US009361073B2

(12) **United States Patent**
Prosak et al.

(10) **Patent No.: US 9,361,073 B2**
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(54) **DEVELOPMENT ENVIRONMENT FOR A SAFETY RELAY CONFIGURATION SYSTEM**

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(73) Assignee: **Rockwell Automation Technologies, Inc.**, Mayfield Heights, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/563,587**

(22) Filed: **Dec. 8, 2014**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**

G06F 9/44	(2006.01)
G05B 19/042	(2006.01)
G05B 19/05	(2006.01)

(52) **U.S. Cl.**

CPC .... ***G06F 8/34*** (2013.01); ***G05B 19/0426*** (2013.01); ***G05B 19/056*** (2013.01); (Continued)

(58) **Field of Classification Search**

CPC G06F 11/3684; G06F 9/4443; G06F 17/30392; G06F 8/34; G01S 7/22; G10L 15/26; G05B 19/0426; G05B 17/02; G05B 2219/13144; G05B 2219/25067

See application file for complete search history.

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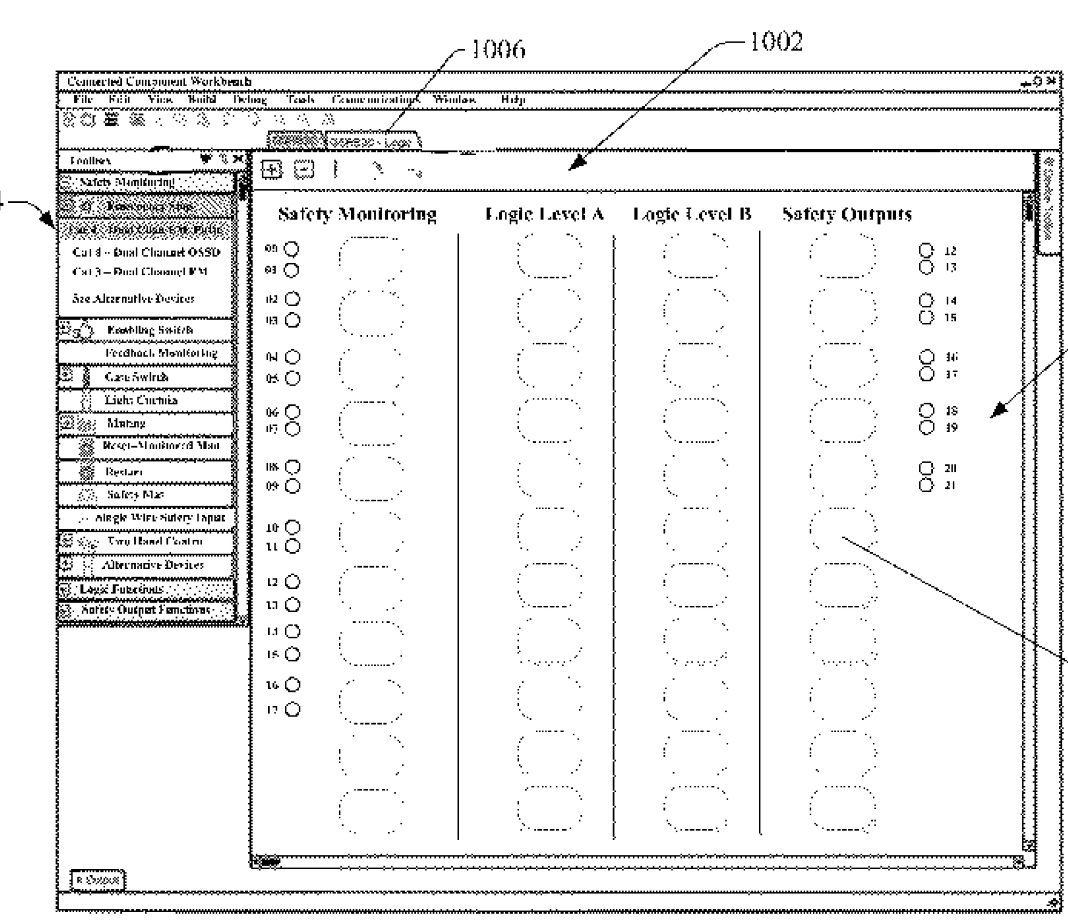
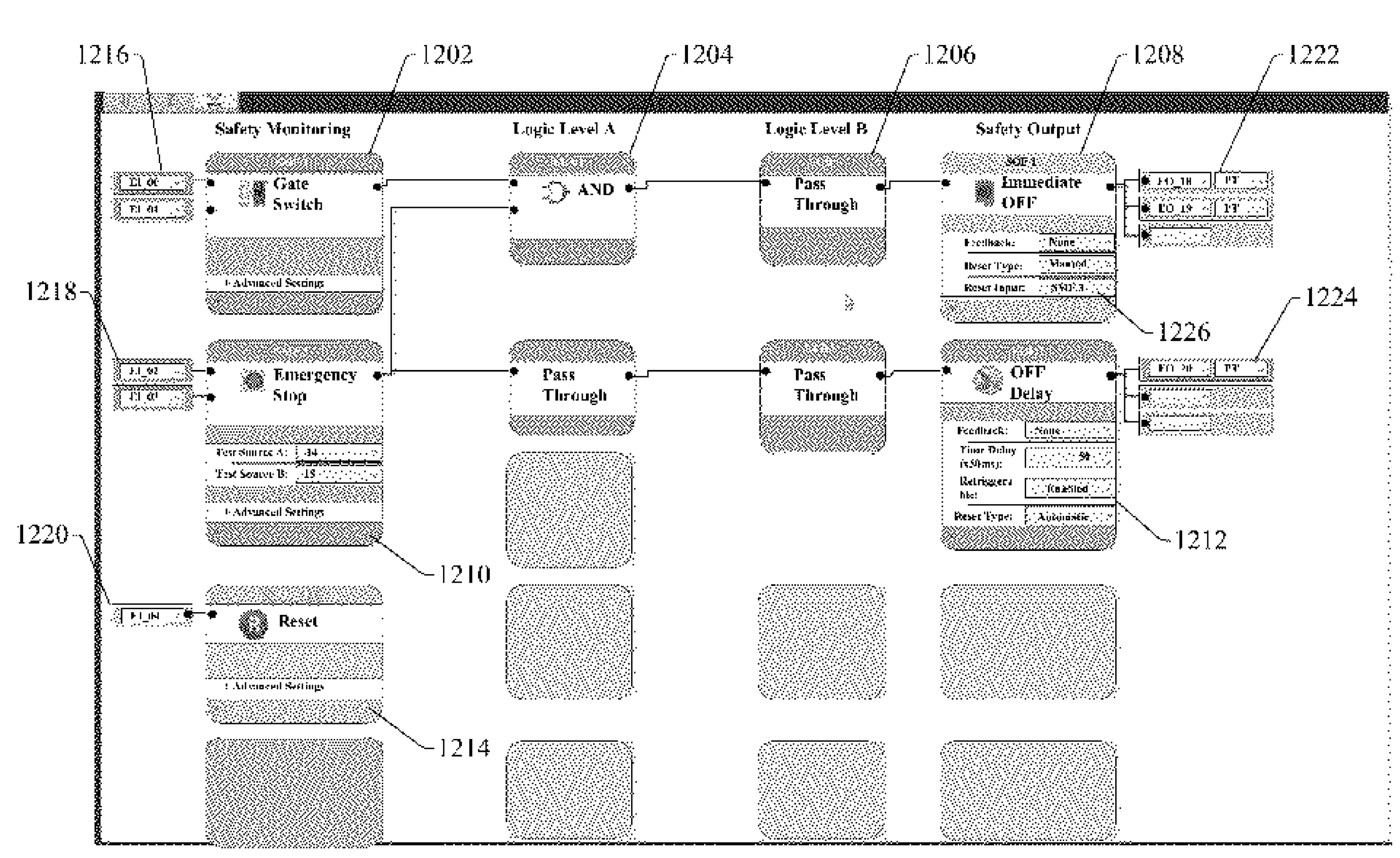
(74) *Attorney, Agent, or Firm* — Amin, Turocy & Watson, LLP

(57) **ABSTRACT**

A safety relay configuration system for configuring safety functions to be carried out by a safety relay is provided. The configuration system comprises a number of features that facilitate intuitive and simplified configuration of an industrial safety relay, including but not limited to features that guide the user through the configuration process using an intuitive sequential procedure that provides feedback and prompts based on user interaction, enforce design consistency throughout the configuration project by intelligently limiting user selections, and visually organize configuration and status information in a manner that efficiently utilizes display space and allows the user to quickly evaluate available configuration options.

20 Claims, 60 Drawing Sheets





(52) **U.S. Cl.**
CPC *G05B 2219/13049* (2013.01); *G05B 2219/13144* (2013.01); *G05B 2219/23278* (2013.01); *G05B 2219/25067* (2013.01)

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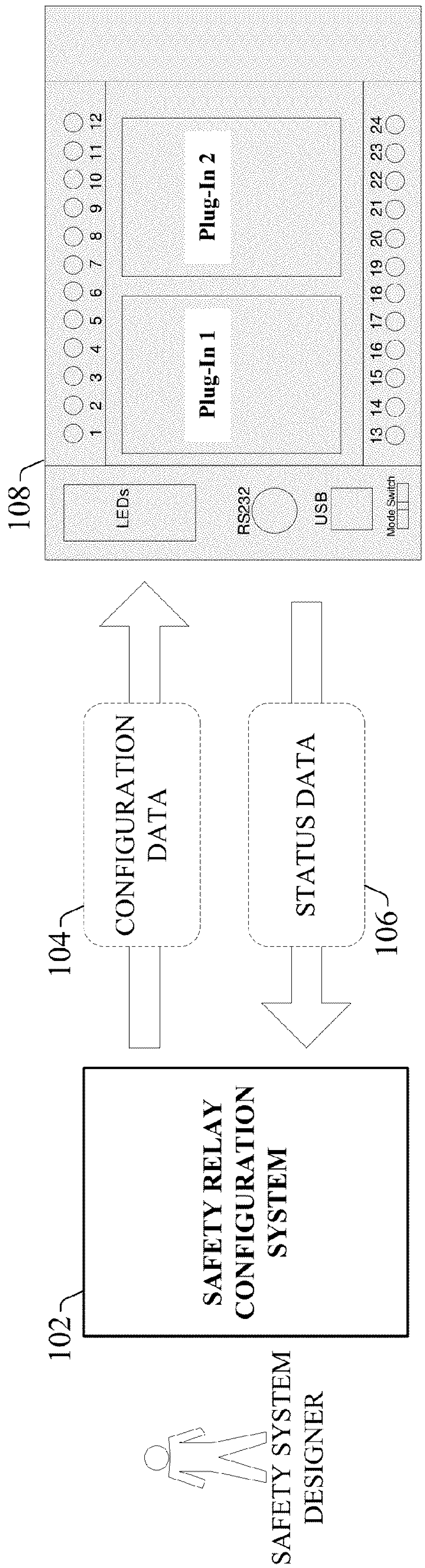

108
LEDs
RS232
USB
Mode Switch
1 2 3 4 5 6 7 8 9 10 11 12
Plug-In 1
Plug-In 2
13 14 15 16 17 18 19 20 21 22 23 24
104
CONFIGURATION DATA
STATUS DATA
106
102
SAFETY RELAY CONFIGURATION SYSTEM
SAFETY SYSTEM DESIGNER

FIG. 1

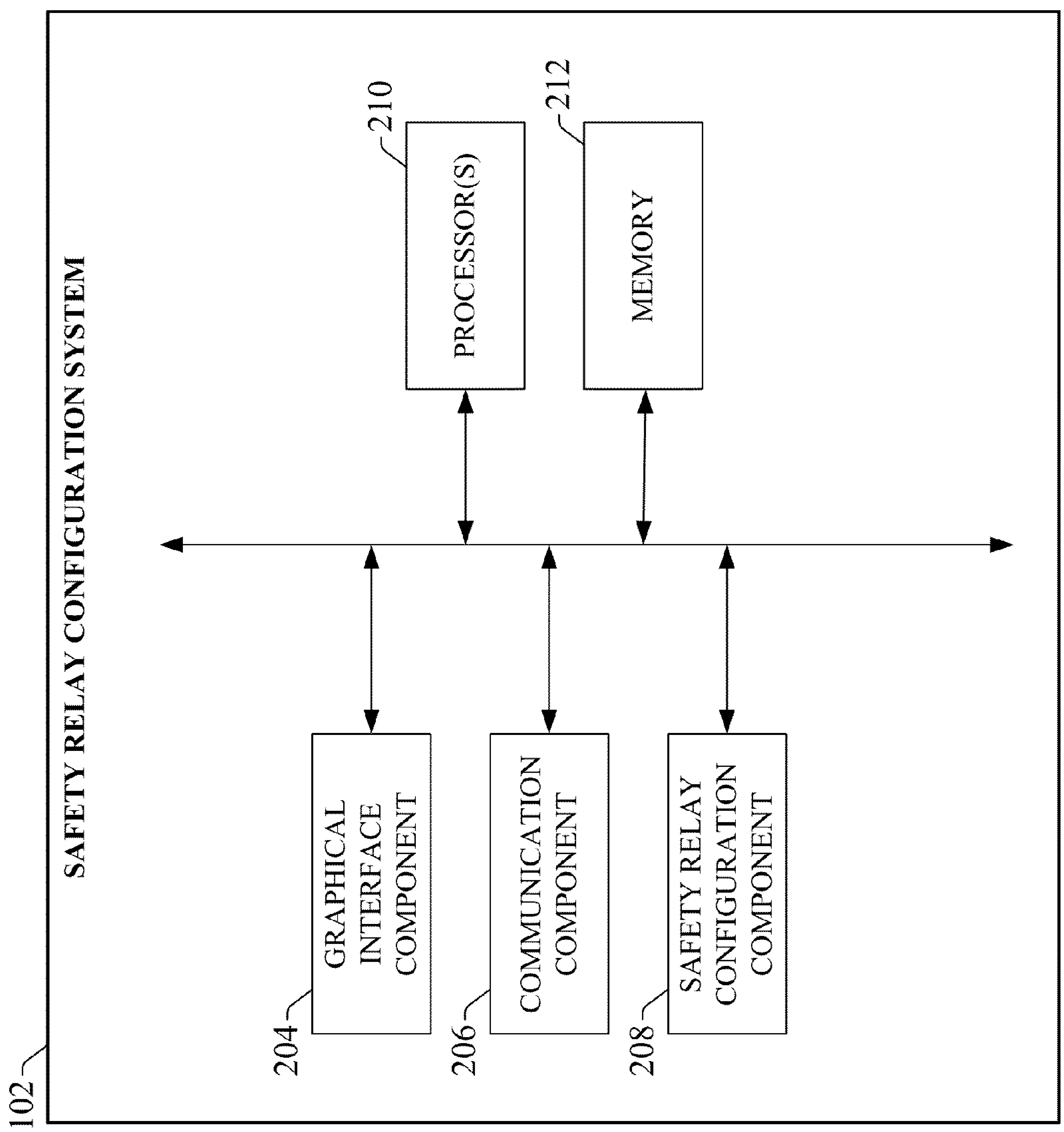

SAFETY RELAY CONFIGURATION SYSTEM
102
GRAPHICAL INTERFACE COMPONENT
204
COMMUNICATION COMPONENT
206
SAFETY RELAY CONFIGURATION COMPONENT
208
PROCESSOR(S)
210
MEMORY
212

FIG. 2

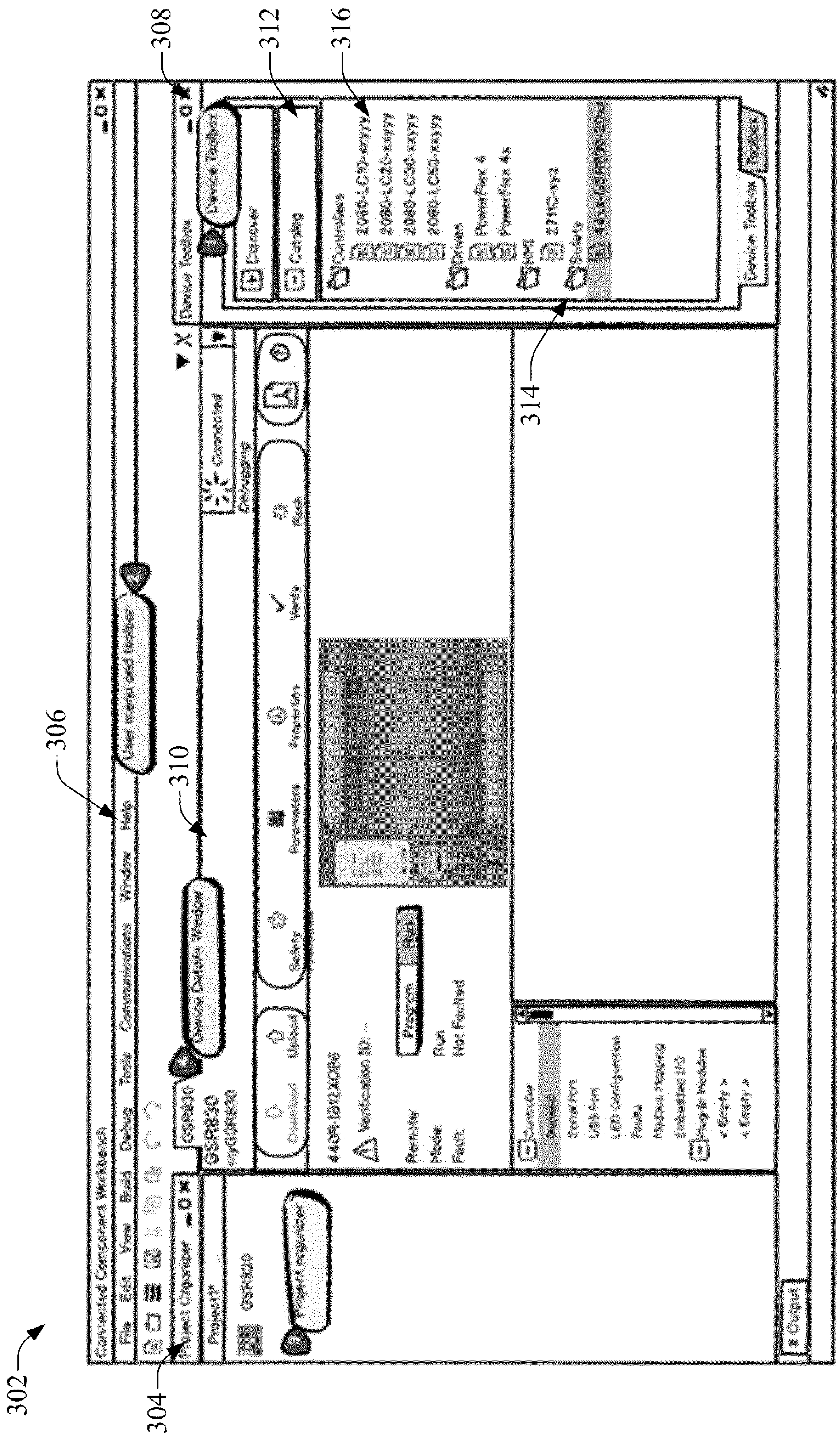

302
304
306
308
310
312
314
316
Connected Component Workbench
File Edit View Build Debug Tools Communications Window Help
Project Organizer
Project1*
GSR830
Project organizer
User menu and toolbar
Device Details Window
GSR830
myGSR830
440R-IB12XOB6
Verification ID: --
Remote:
Mode: Run
Fault: Not Faulted
Program
Run
Download
Upload
Safety
Parameters
Properties
Verify
Flash
Connected
Debugging
Controller
General
Serial Port
USB Port
LED Configuration
Faults
Modbus Mapping
Embedded I/O
Plug-In Modules
< Empty >
< Empty >
Device Toolbox
Discover
Catalog
Controllers
2080-LC10-xxyyy
2080-LC20-xxyyy
2080-LC30-xxyyy
2080-LC50-xxyyy
Drives
PowerFlex 4
PowerFlex 4x
HMI
2711C-xyz
Safety
44xx-GSR830-20-...
Device Toolbox
Toolbox
Output

FIG. 3

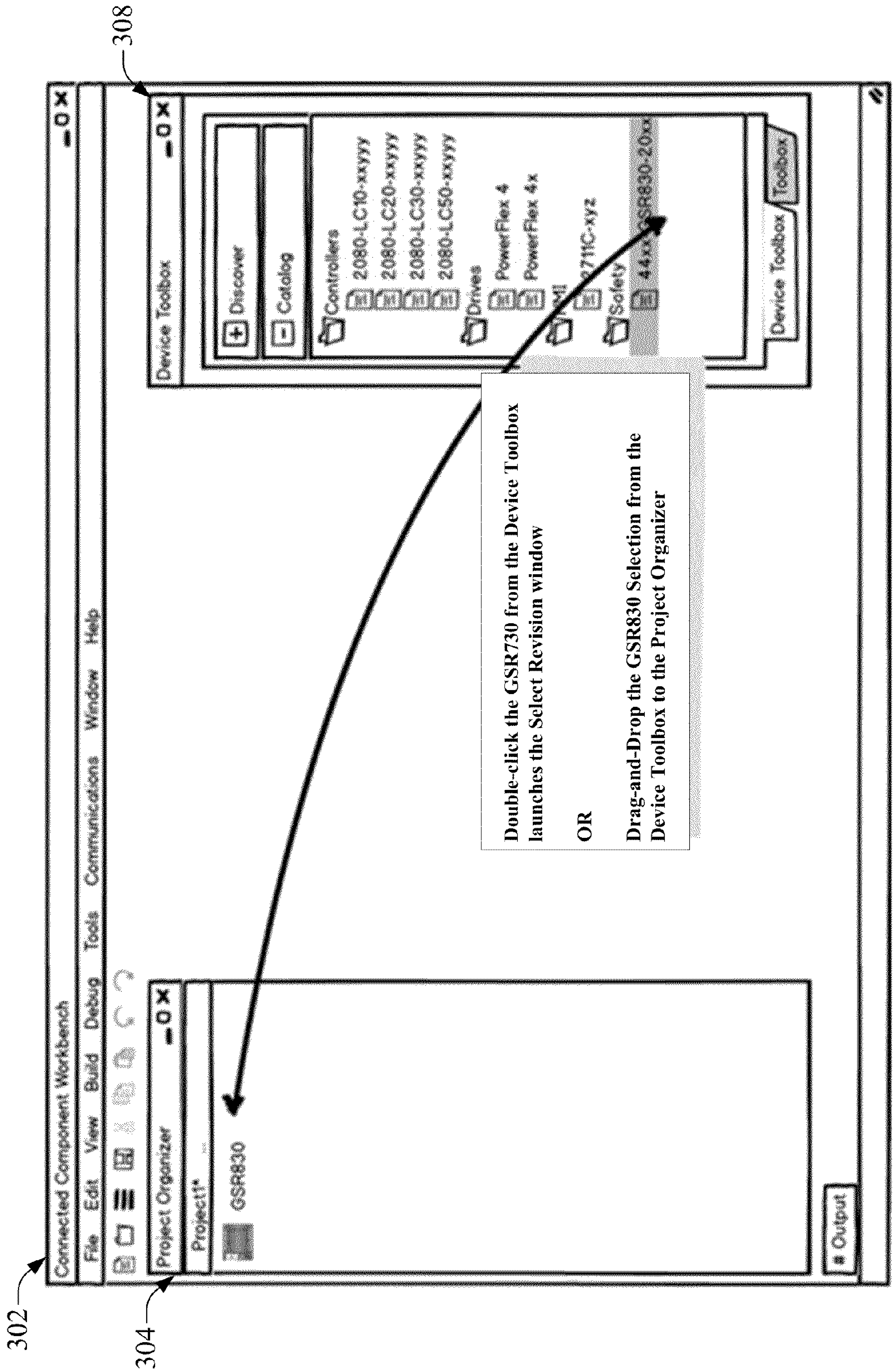

302
304
308
Connected Component Workbench
File Edit View Build Debug Tools Communications Window Help
Project Organizer
Project1*
GSR830
Device Toolbox
Discover
Catalog
Controllers
2080-LC10-xxyyy
2080-LC20-xxyyy
2080-LC30-xxyyy
2080-LC50-xxyyy
Drives
PowerFlex 4
PowerFlex 4x
Safety
Device Toolbox
Toolbox
Output
Double-click the GSR730 from the Device Toolbox launches the Select Revision window
OR
Drag-and-Drop the GSR830 Selection from the Device Toolbox to the Project Organizer

FIG. 4

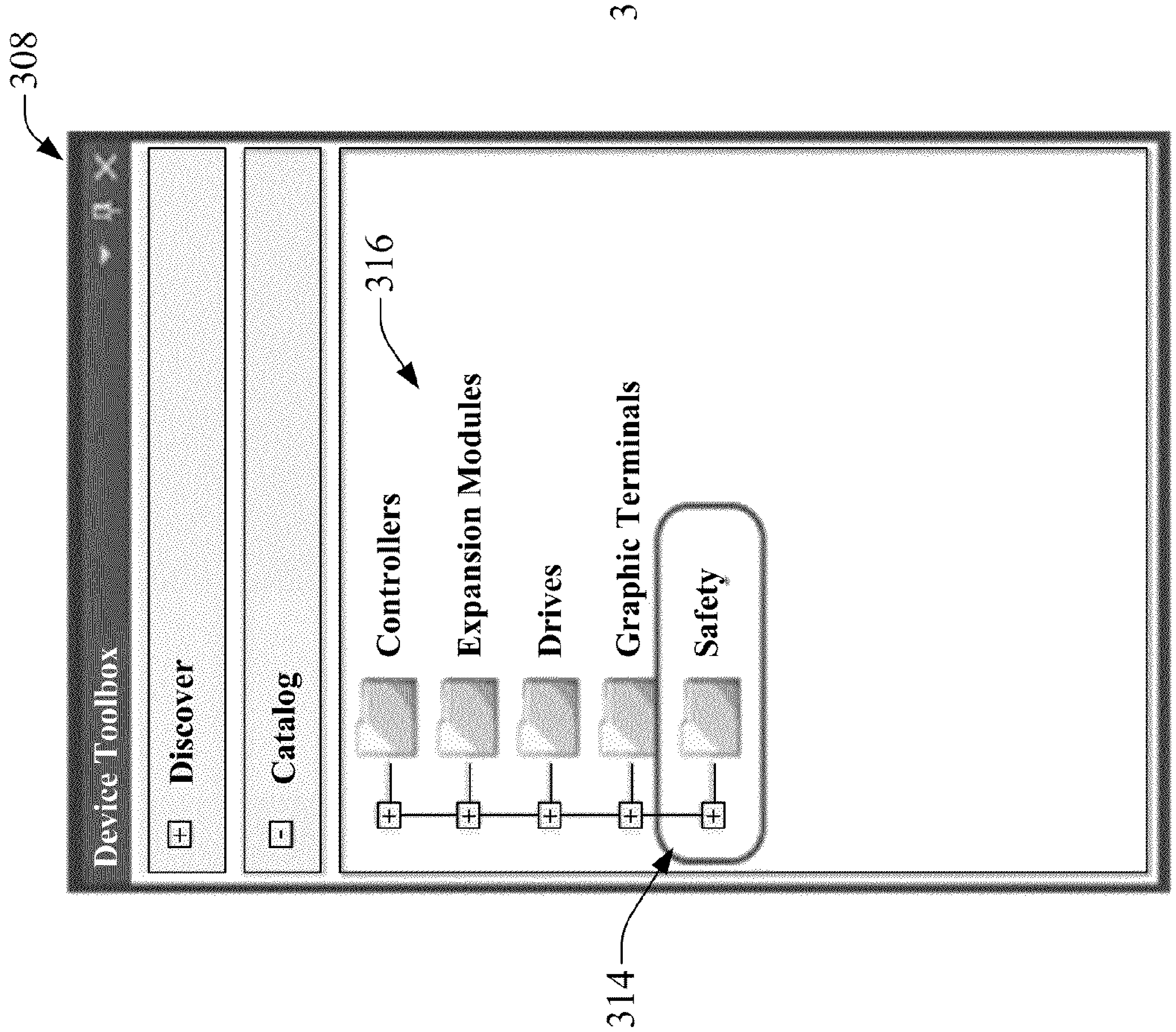

308
Device Toolbox
Discover
Catalog
316
Controllers
Expansion Modules
Drives
Graphic Terminals
Safety
314

FIG. 5a

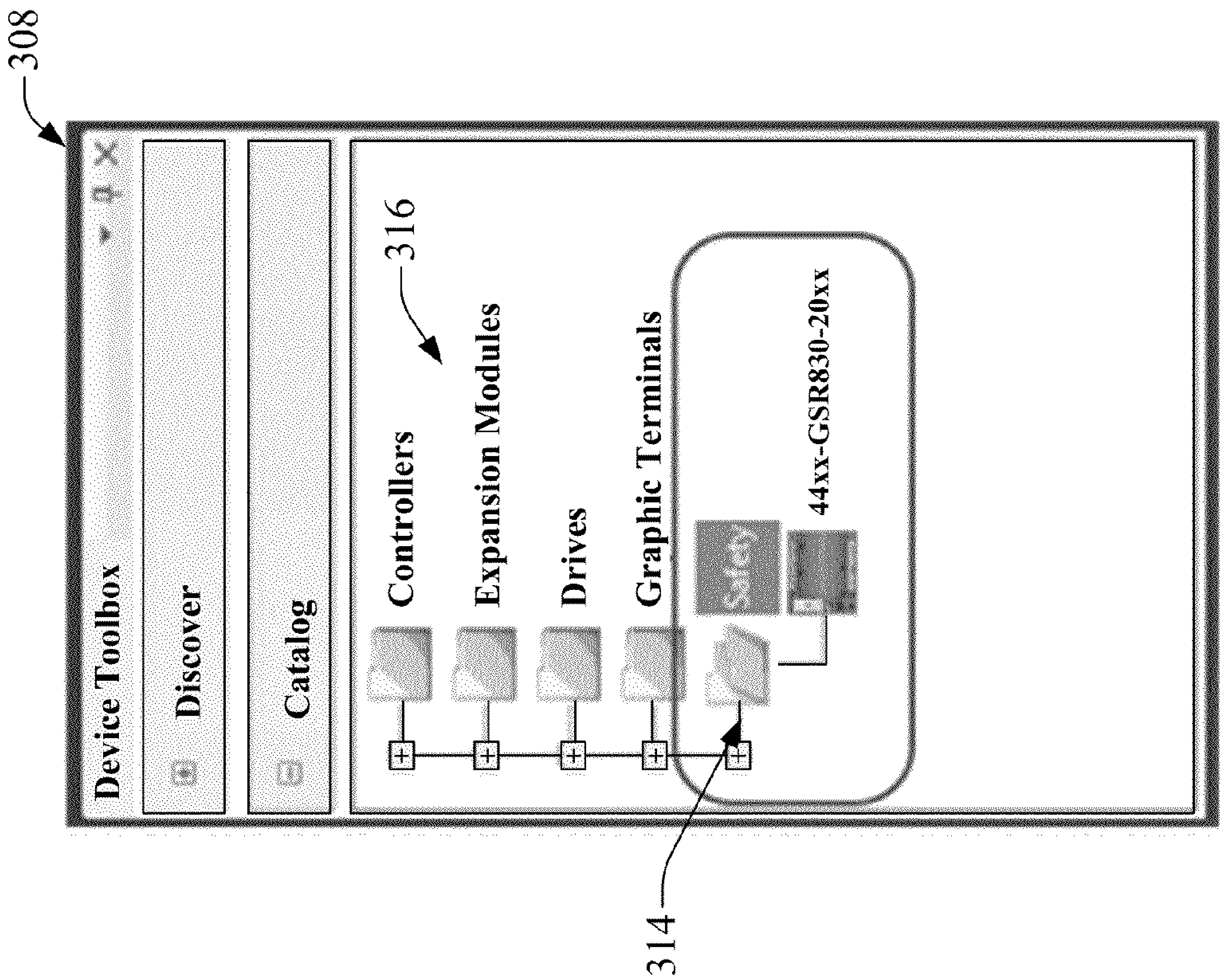

308
Device Toolbox
Discover
Catalog
316
Controllers
Expansion Modules
Drives
Graphic Terminals
Safety
44xx-GSR830-20xx
314

FIG. 5b

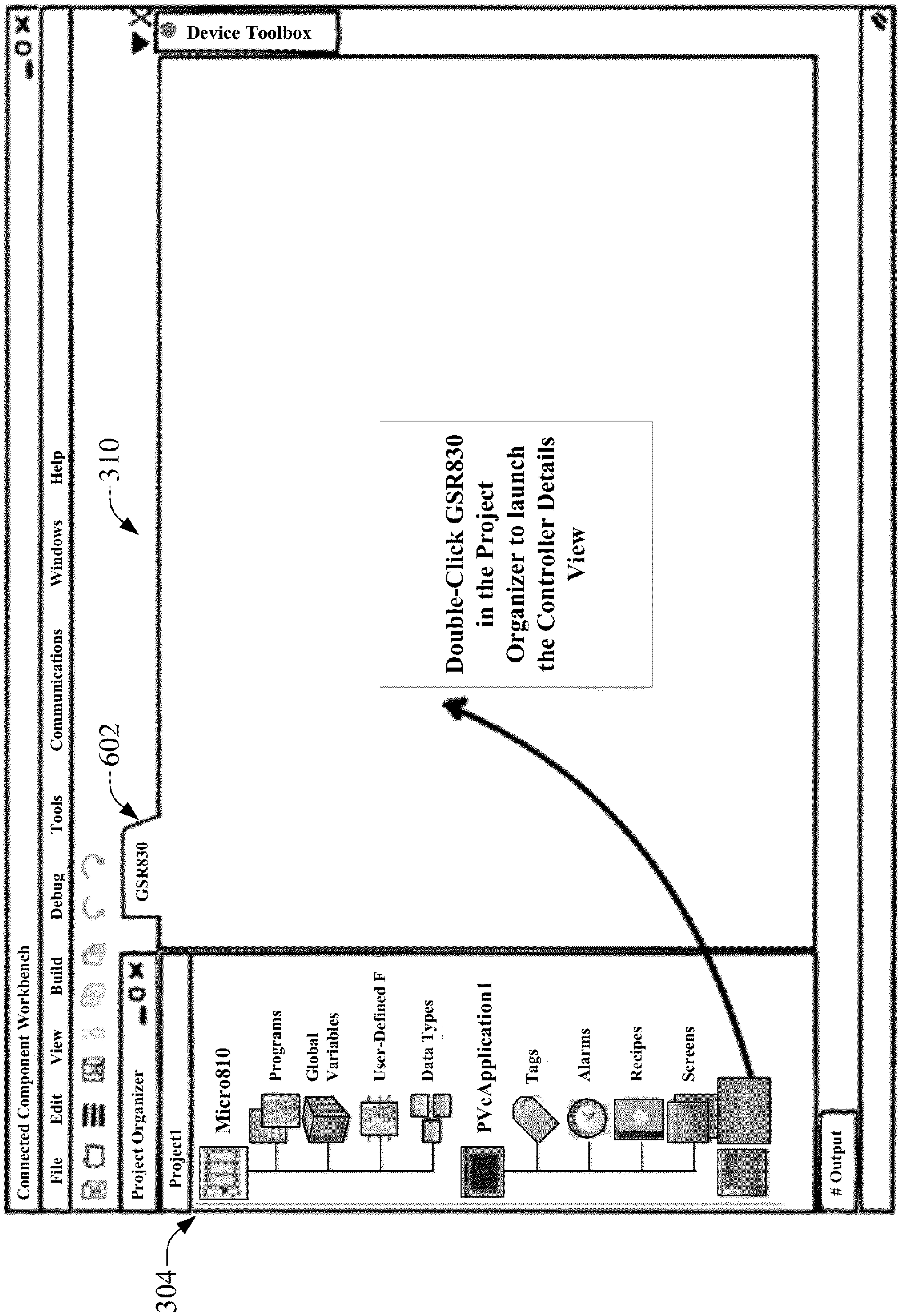

Connected Component Workbench
File
Edit
View
Build
Debug
Tools
Communications
Windows
Help
Project Organizer
Project1
Micro810
Programs
Global Variables
User-Defined F
Data Types
PVcApplication1
Tags
Alarms
Recipes
Screens
GSR830
Output
GSR830
602
310
Device Toolbox
Double-Click GSR830 in the Project Organizer to launch the Controller Details View
304

FIG. 6

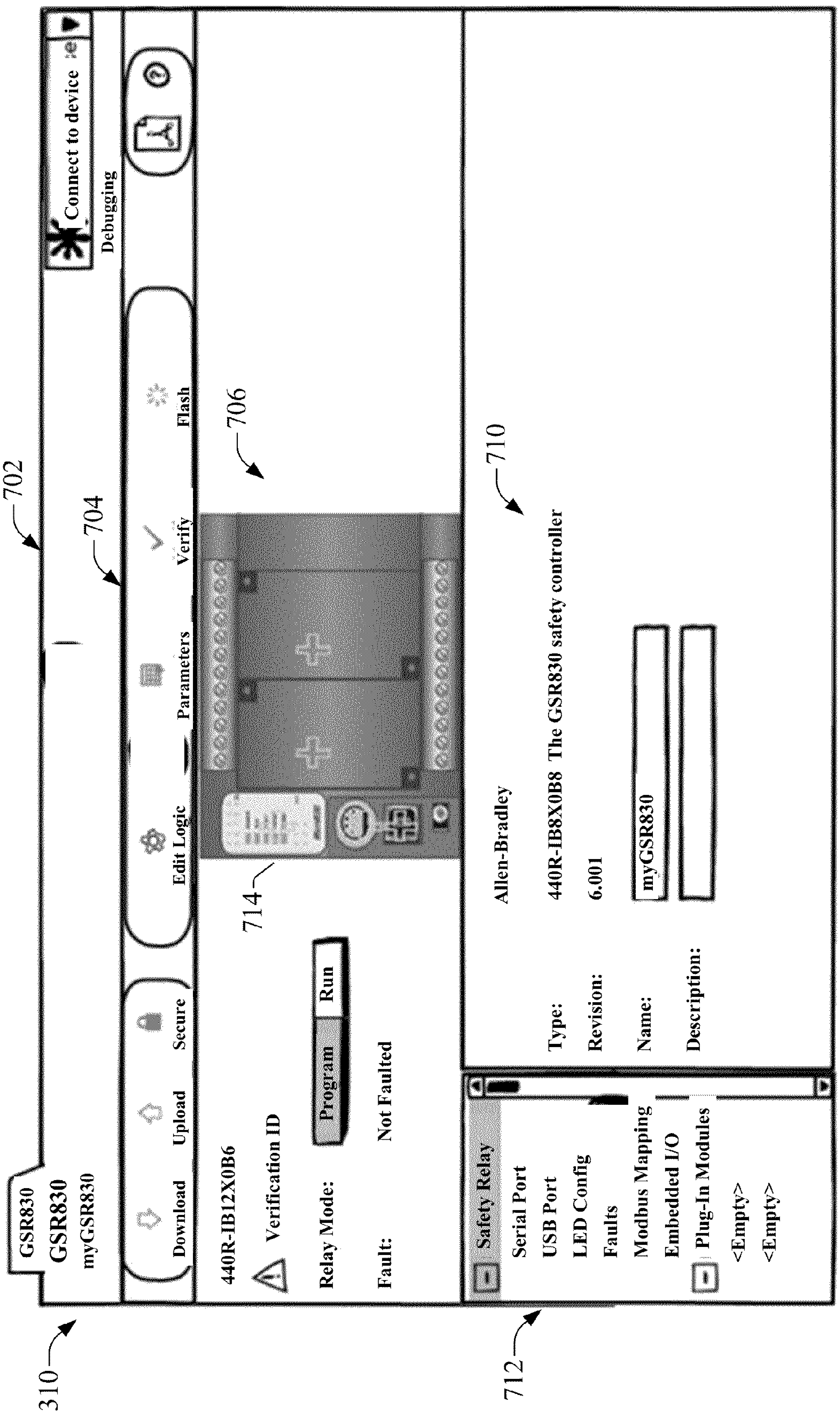

GSR830
GSR830
myGSR830
Connect to device
Debugging
Download
Upload
Secure
Edit Logic
Parameters
Verify
Flash
440R-IB12X0B6
Verification ID
Relay Mode:
Program
Run
Fault:
Not Faulted
Safety Relay
Serial Port
USB Port
LED Config
Faults
Modbus Mapping
Embedded I/O
Plug-In Modules
<Empty>
<Empty>
Allen-Bradley
Type:
440R-IB8X0B8 The GSR830 safety controller
Revision:
6.001
Name:
myGSR830
Description:
310
702
704
706
710
712
714

FIG. 7

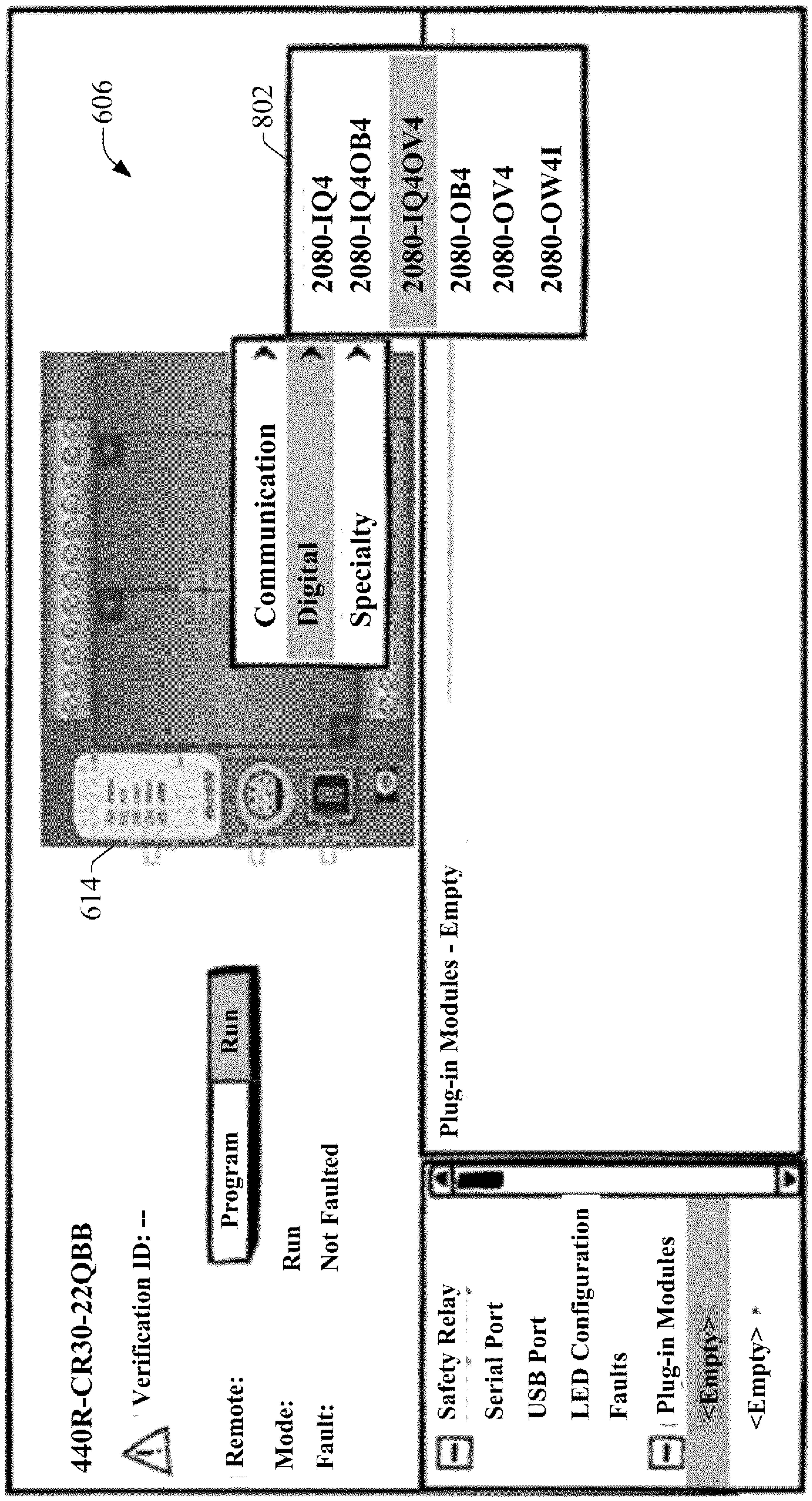

606
802
614
440R-CR30-22QBB
Verification ID: --
Remote:
Mode:
Fault:
Program
Run
Run
Not Faulted
Communication
Digital
Specialty
2080-IQ4
2080-IQ4OB4
2080-IQ4OV4
2080-OB4
2080-OV4
2080-OW4I
Plug-in Modules - Empty
Safety Relay
Serial Port
USB Port
LED Configuration
Faults
Plug-in Modules
<Empty>
<Empty>

FIG. 8

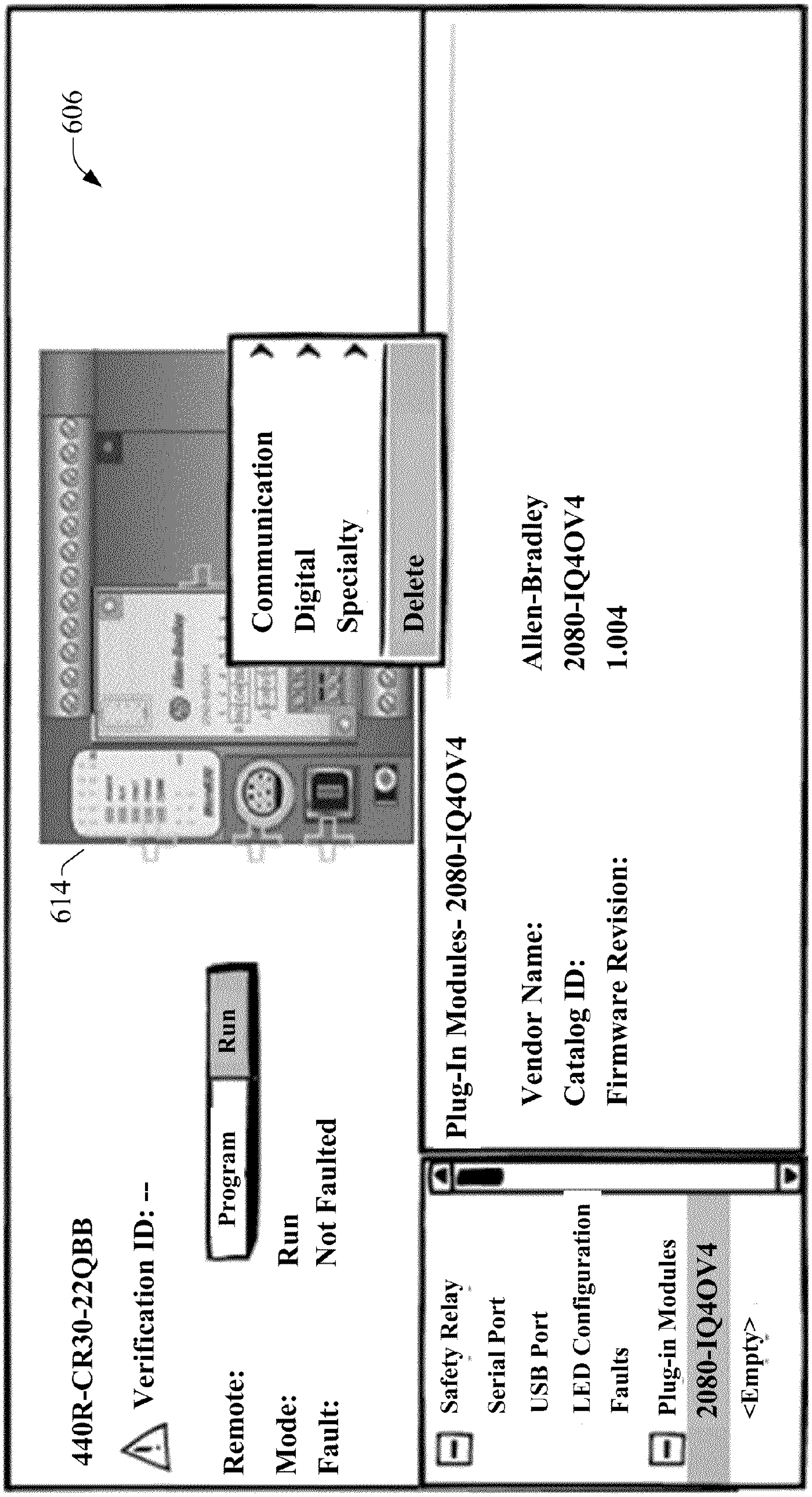

606
614
440R-CR30-22QBB
Verification ID: --
Remote:
Program
Run
Mode: Run
Fault: Not Faulted
Communication
Digital
Specialty
Delete
Safety Relay
Serial Port
USB Port
LED Configuration
Faults
Plug-in Modules
2080-IQ4OV4
<Empty>
Plug-In Modules- 2080-IQ4OV4
Vendor Name: Allen-Bradley
Catalog ID: 2080-IQ4OV4
Firmware Revision: 1.004

FIG. 9

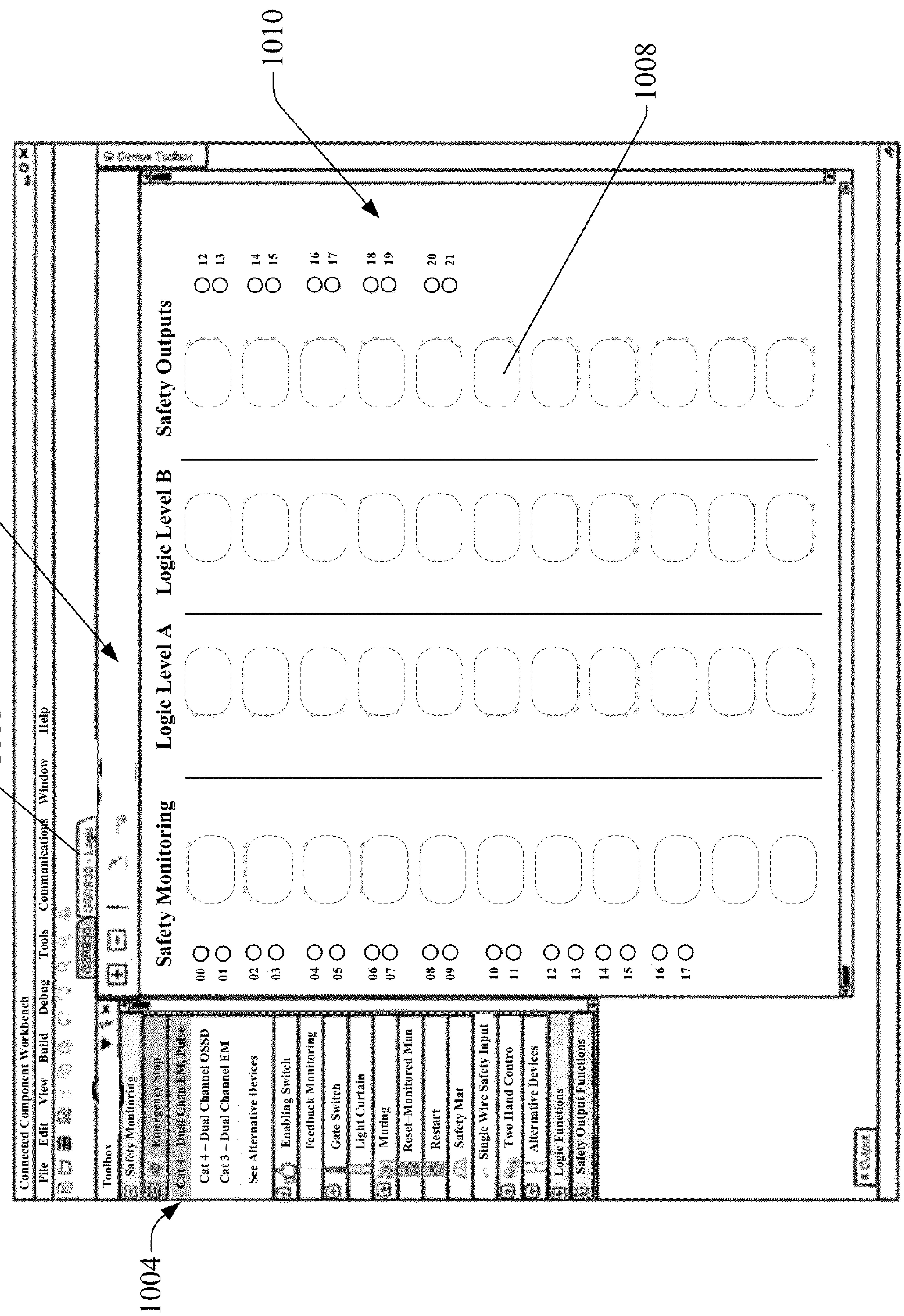

1010
1008
1002
1006
1004
Connected Component Workbench
File Edit View Build Debug Tools Communications Window Help
GSR830
GSR830 - Logic
Device Toolbox
Toolbox
Safety Monitoring
Emergency Stop
Cat 4 – Dual Chan EM, Pulse
Cat 4 – Dual Channel OSSD
Cat 3 – Dual Channel EM
See Alternative Devices
Enabling Switch
Feedback Monitoring
Gate Switch
Light Curtain
Muting
Reset–Monitored Man
Restart
Safety Mat
Single Wire Safety Input
Two Hand Contro
Alternative Devices
Logic Functions
Safety Output Functions
Output
Safety Monitoring
Logic Level A
Logic Level B
Safety Outputs
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
12
13
14
15
16
17
18
19
20
21

FIG. 10

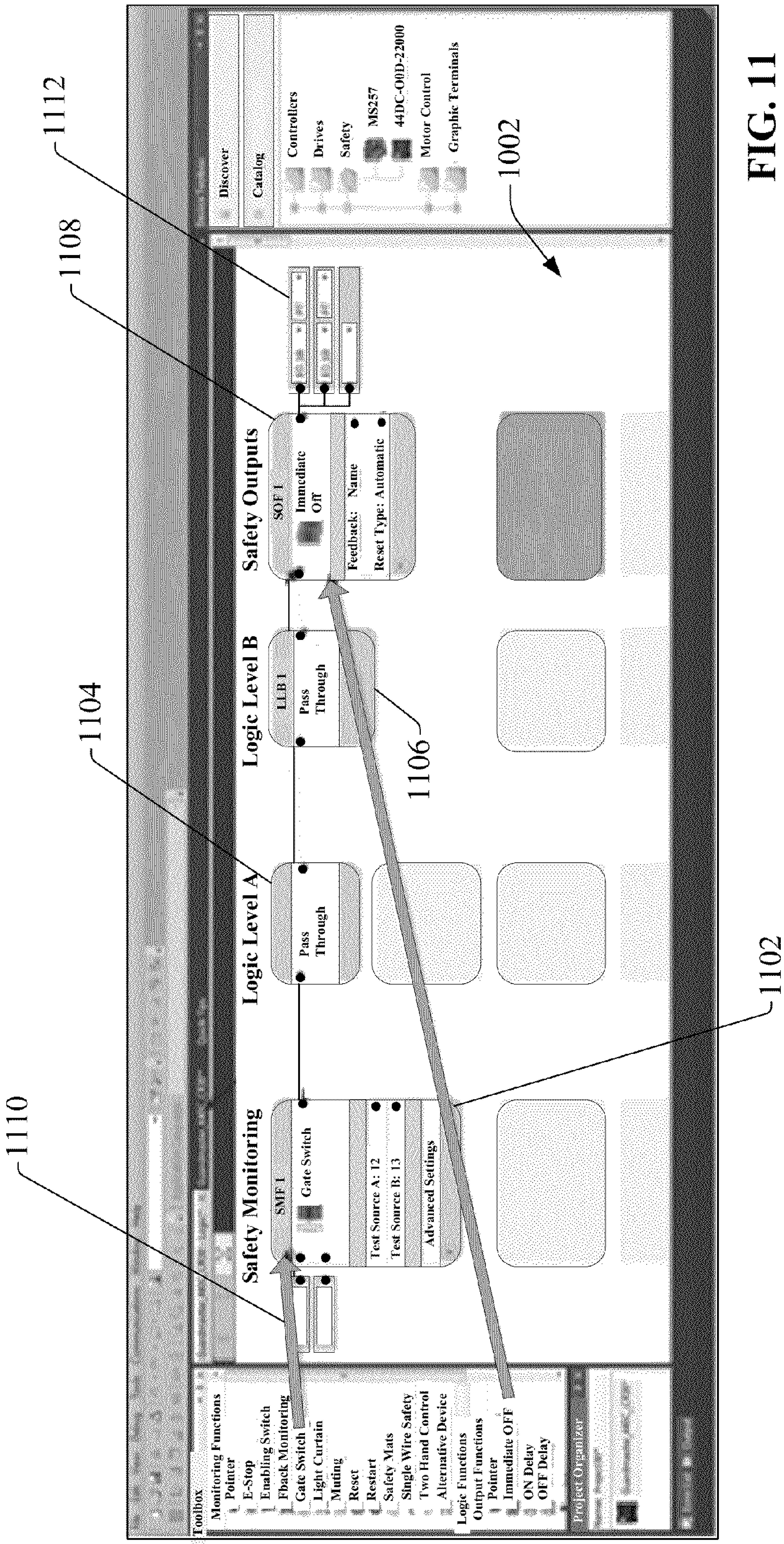
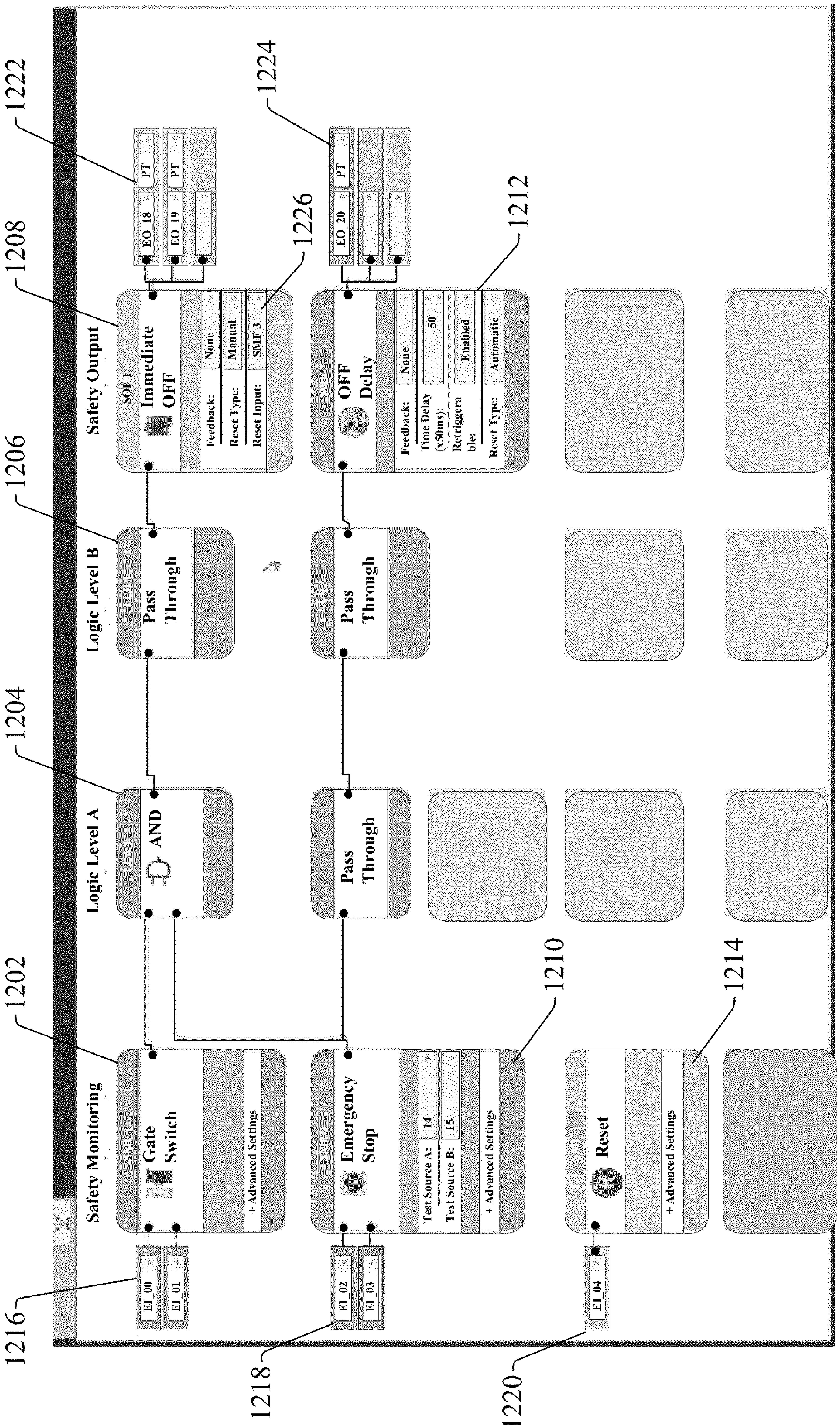

1110
1104
1108
1112
1106
1102
1002
Safety Monitoring
SMF 1
Gate Switch
Test Source A: 12
Test Source B: 13
Advanced Settings
Logic Level A
Pass Through
Logic Level B
LLB 1
Pass Through
Safety Outputs
SOF 1
Immediate Off
Feedback: Name
Reset Type: Automatic
Discover
Catalog
Controllers
Drives
Safety
MS257
44DC-O0D-22000
Motor Control
Graphic Terminals
Toolbox
Monitoring Functions
Pointer
E-Stop
Enabling Switch
Fback Monitoring
Gate Switch
Light Curtain
Muting
Reset
Restart
Safety Mats
Single Wire Safety
Two Hand Control
Alternative Device
Logic Functions
Output Functions
Pointer
Immediate OFF
ON Delay
OFF Delay
Project Organizer

FIG. 11



1202
1204
1206
1208
1210
1212
1214
1216
1218
1220
1222
1224
1226
Safety Monitoring
Logic Level A
Logic Level B
Safety Output
SMF 1
Gate Switch
+ Advanced Settings
SMF 2
Emergency Stop
Test Source A: 14
Test Source B: 15
+ Advanced Settings
SMF 3
Reset
+ Advanced Settings
AND
Pass Through
Pass Through
Pass Through
SOF 1
Immediate OFF
Feedback: None
Reset Type: Manual
Reset Input: SMF 3
SOF 2
OFF Delay
Feedback: None
Time Delay (x50ms): 50
Retriggerable: Enabled
Reset Type: Automatic
EI_00
EI_01
EI_02
EI_03
EI_04
EO 18
EO 19
EO 20
PT
PT
PT

FIG. 12

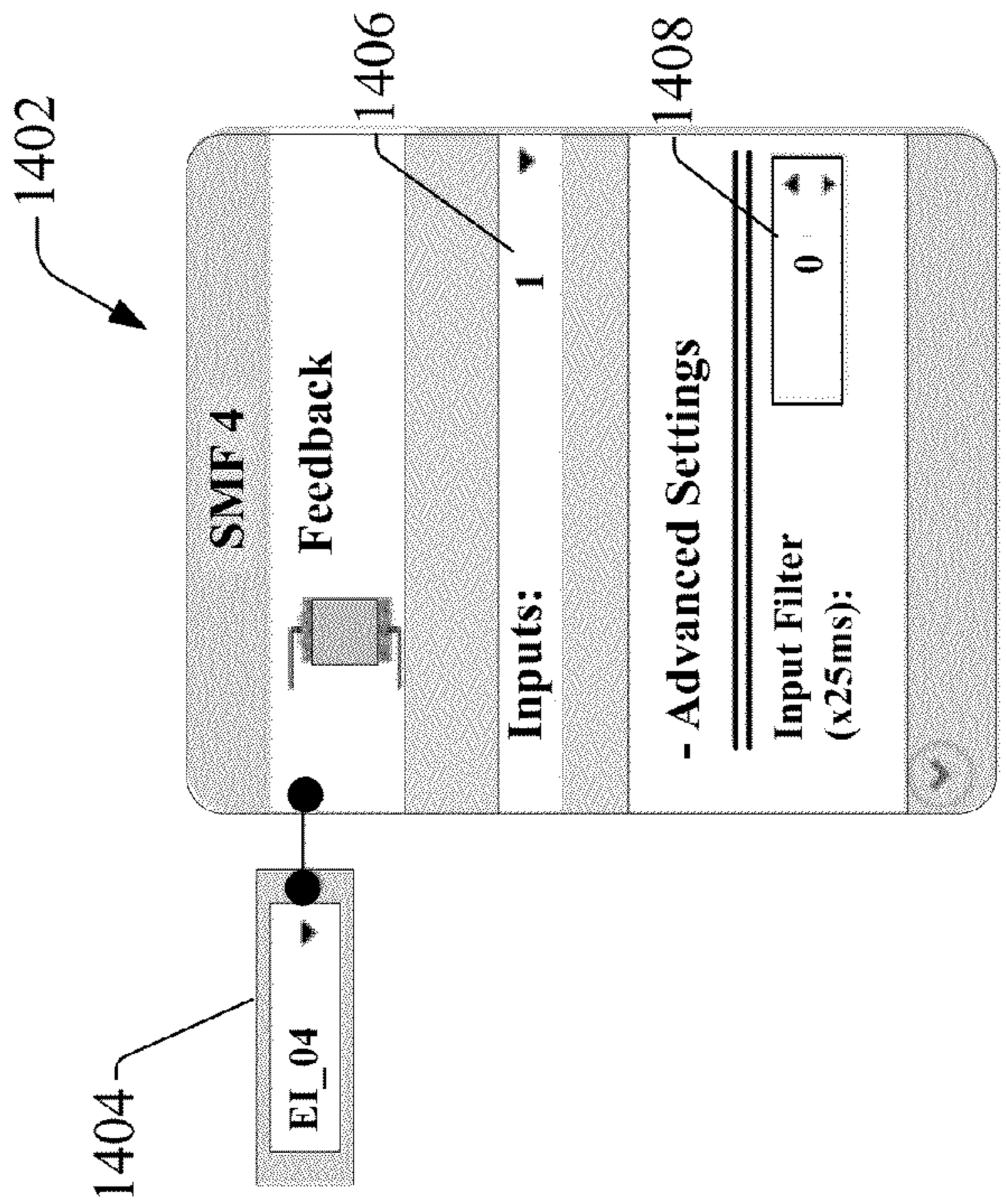

1402
1404
1406
1408
EI_04
SMF 4
Feedback
Inputs:
1
- Advanced Settings
Input Filter
(x25ms):
0

FIG. 14

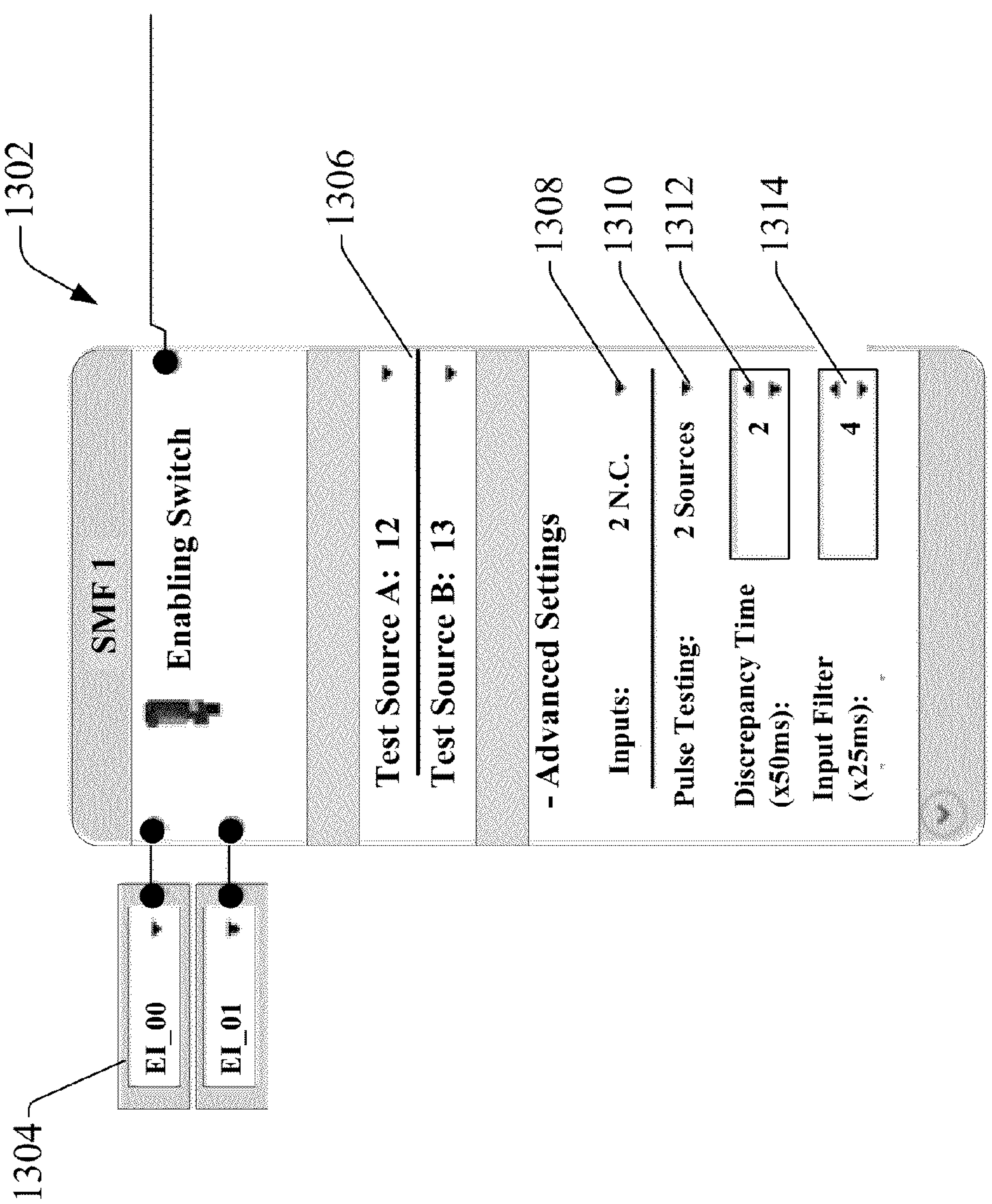

1302
1304
1306
1308
1310
1312
1314
EI_00
EI_01
SMF 1
Enabling Switch
Test Source A: 12
Test Source B: 13
- Advanced Settings
Inputs:
2 N.C.
Pulse Testing:
2 Sources
Discrepancy Time
(x50ms):
2
Input Filter
(x25ms):
4

FIG. 13

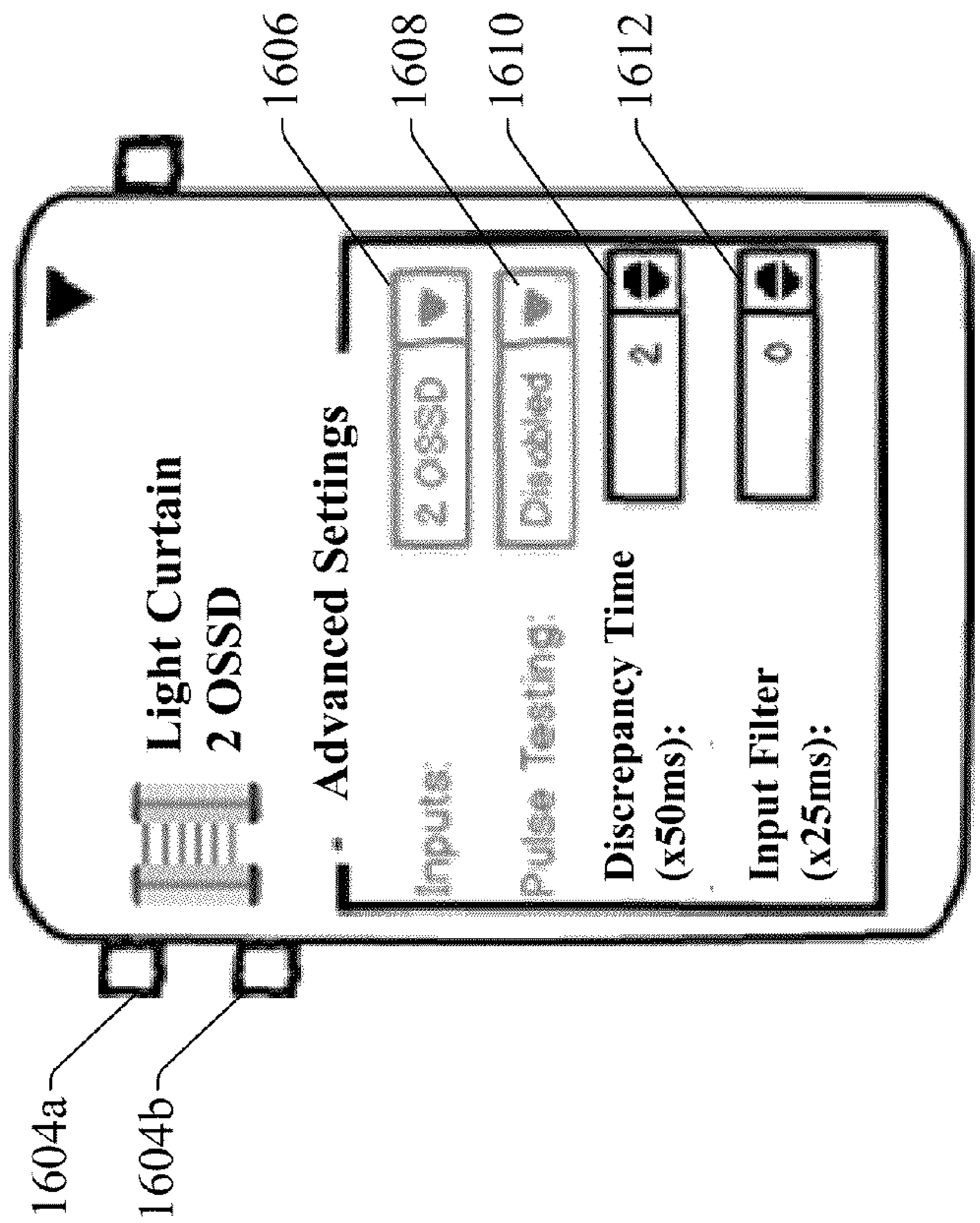

1602
1606
1608
1610
1612
1604a
1604b
Light Curtain
2 OSSD
- Advanced Settings
Inputs:
2 OSSD
Pulse Testing:
Disabled
Discrepancy Time
(x50ms):
2
Input Filter
(x25ms):
0

FIG. 16

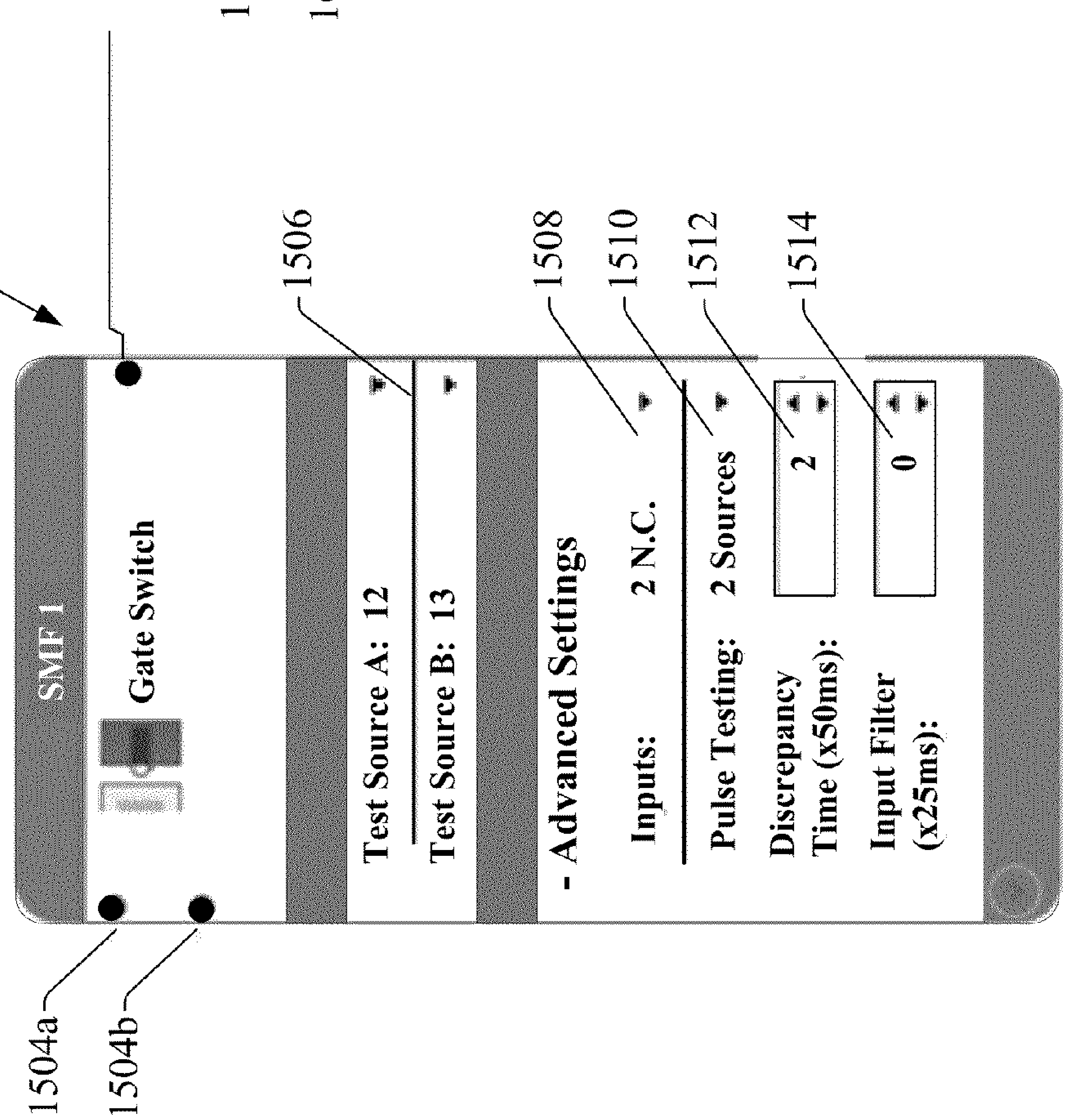

1502
1504a
1504b
1506
1508
1510
1512
1514
SMF 1
Gate Switch
Test Source A: 12
Test Source B: 13
- Advanced Settings
Inputs: 2 N.C.
Pulse Testing: 2 Sources
Discrepancy Time (x50ms):
2
Input Filter (x25ms):
0

FIG. 15

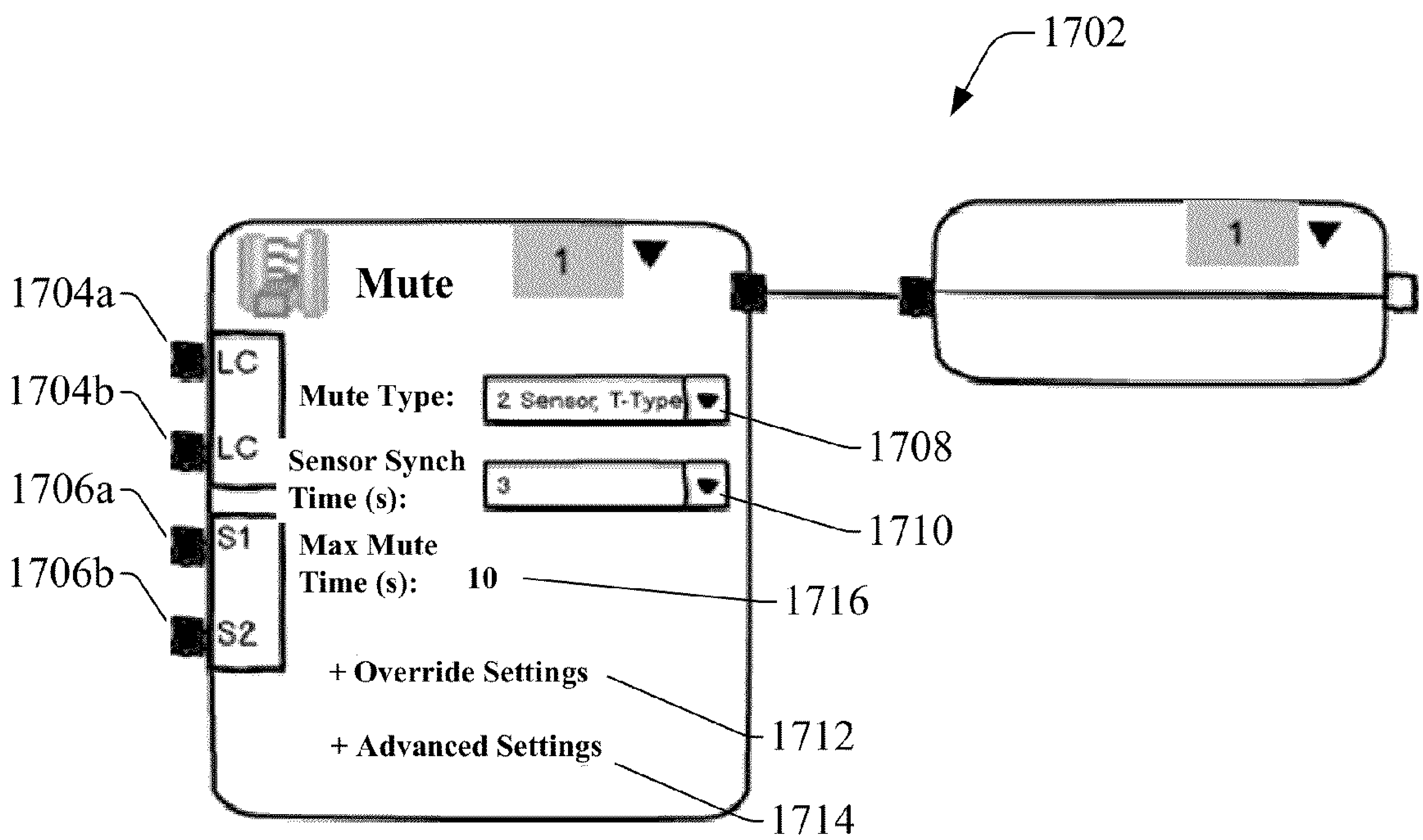
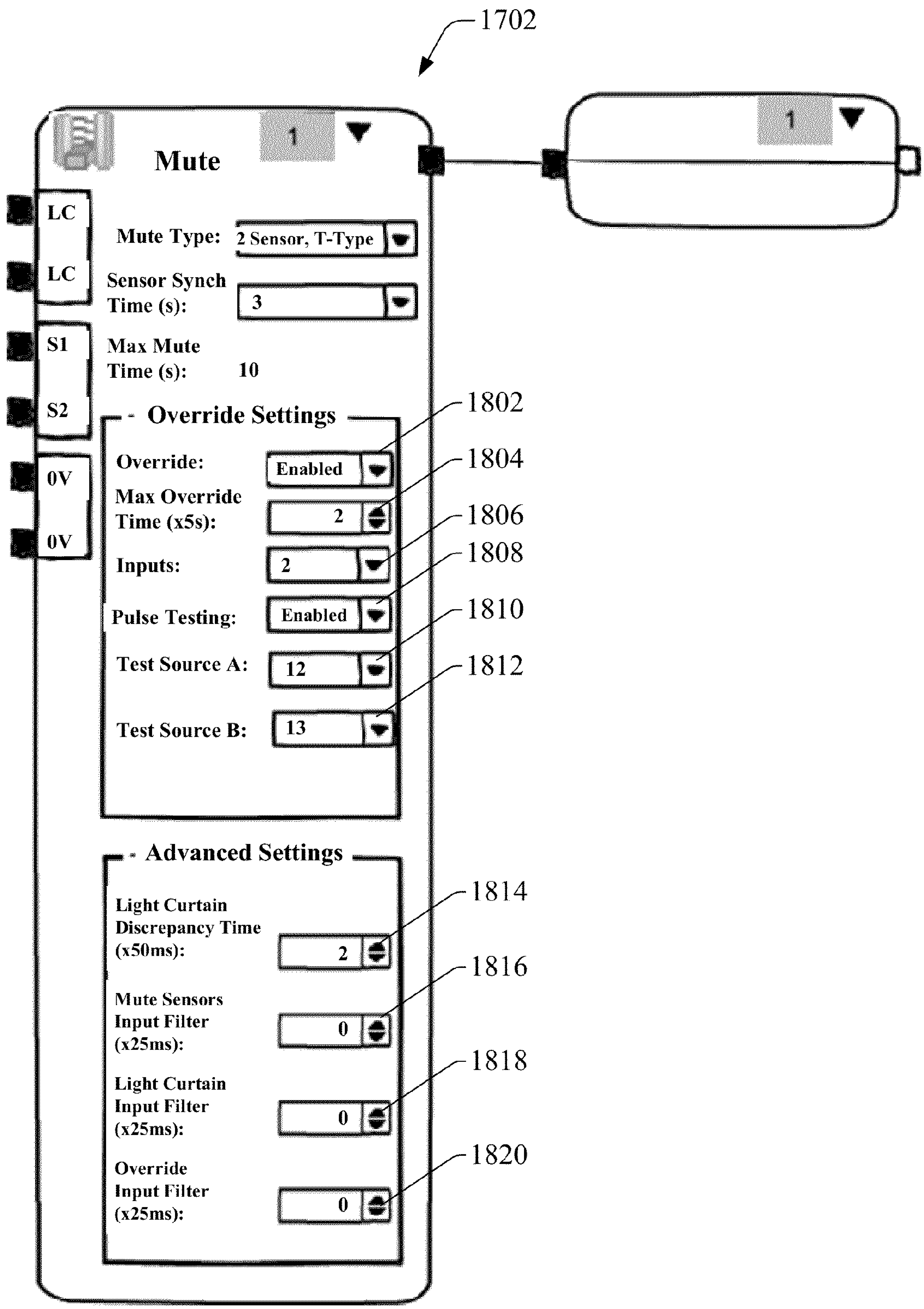

1702
Mute
1
1
1704a
LC
1704b
LC
Mute Type:
2 Sensor, T-Type
1708
Sensor Synch
Time (s):
3
1710
1706a
S1
Max Mute
Time (s):
10
1716
1706b
S2
+ Override Settings
1712
+ Advanced Settings
1714

FIG. 17



1702
1
Mute
1
LC
LC
S1
S2
0V
0V
Mute Type:
2 Sensor, T-Type
Sensor Synch
Time (s):
3
Max Mute
Time (s):
10
Override Settings
Override:
Enabled
Max Override
Time (x5s):
2
Inputs:
2
Pulse Testing:
Enabled
Test Source A:
12
Test Source B:
13
1802
1804
1806
1808
1810
1812
Advanced Settings
Light Curtain
Discrepancy Time
(x50ms):
2
Mute Sensors
Input Filter
(x25ms):
0
Light Curtain
Input Filter
(x25ms):
0
Override
Input Filter
(x25ms):
0
1814
1816
1818
1820

FIG. 18

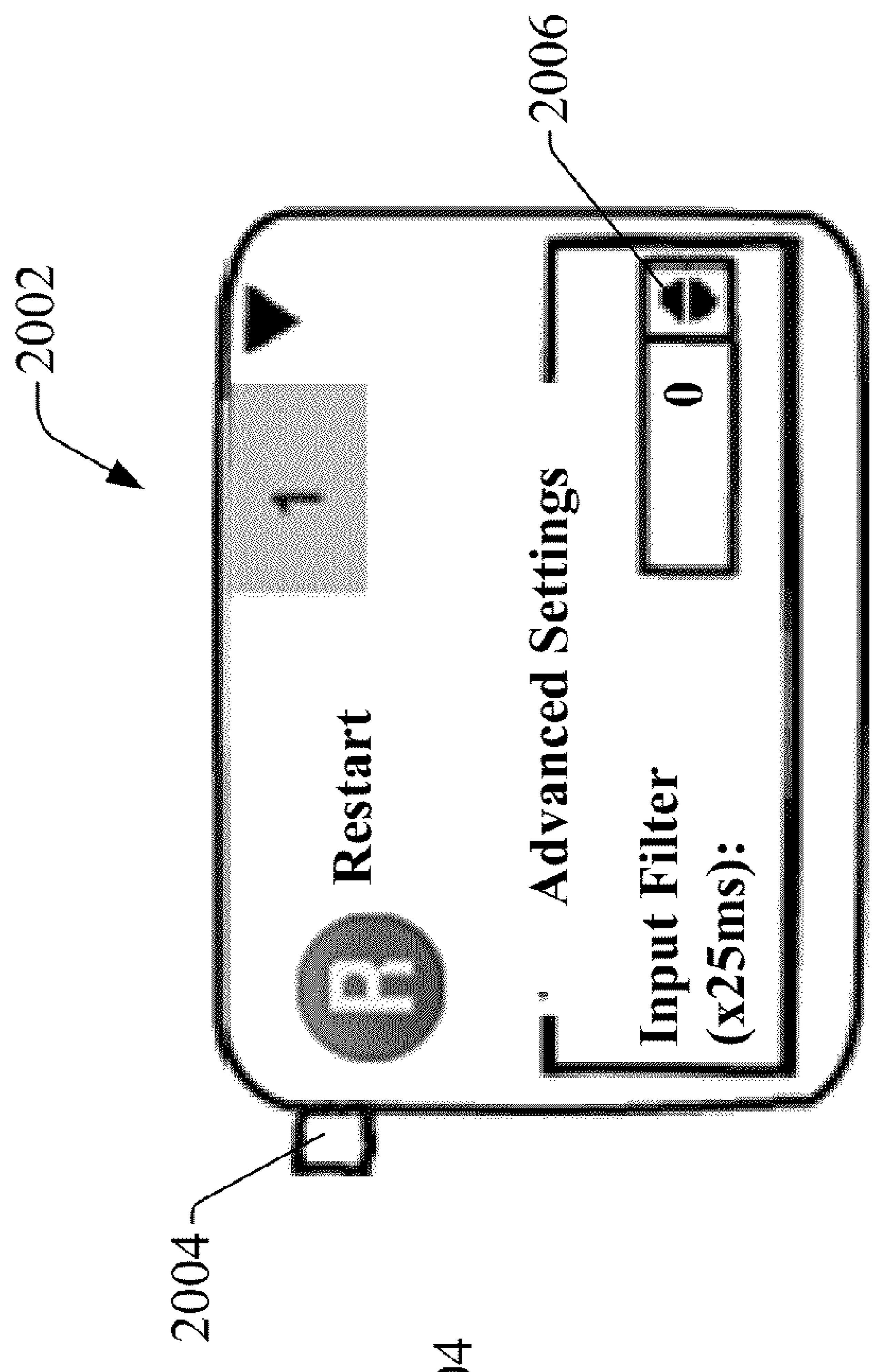

2002
2004
2006
Restart
1
Advanced Settings
Input Filter
(x25ms):
0

FIG. 20

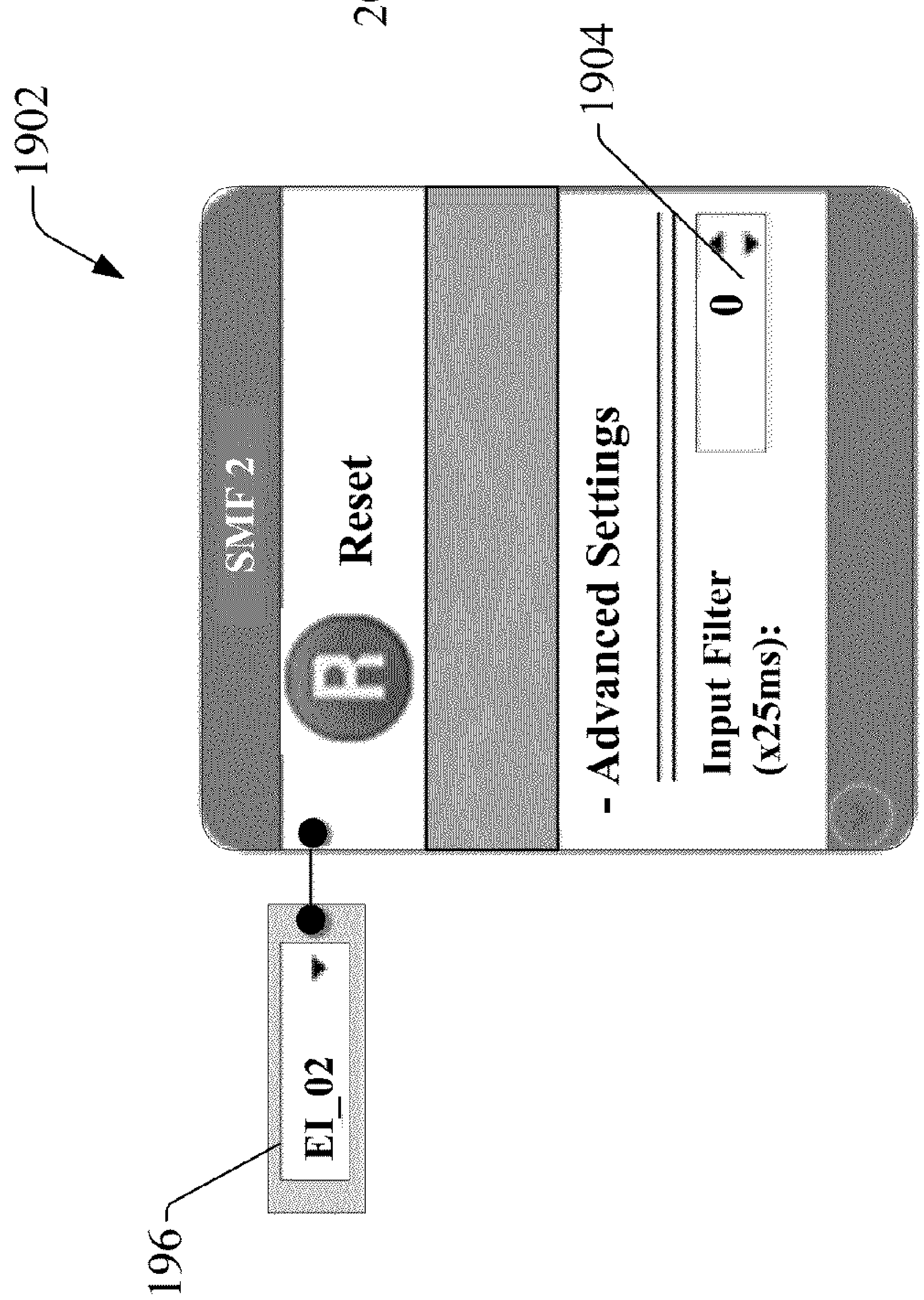

1902
1904
196
EI_02
SMF 2
Reset
- Advanced Settings
Input Filter
(x25ms):
0

FIG. 19

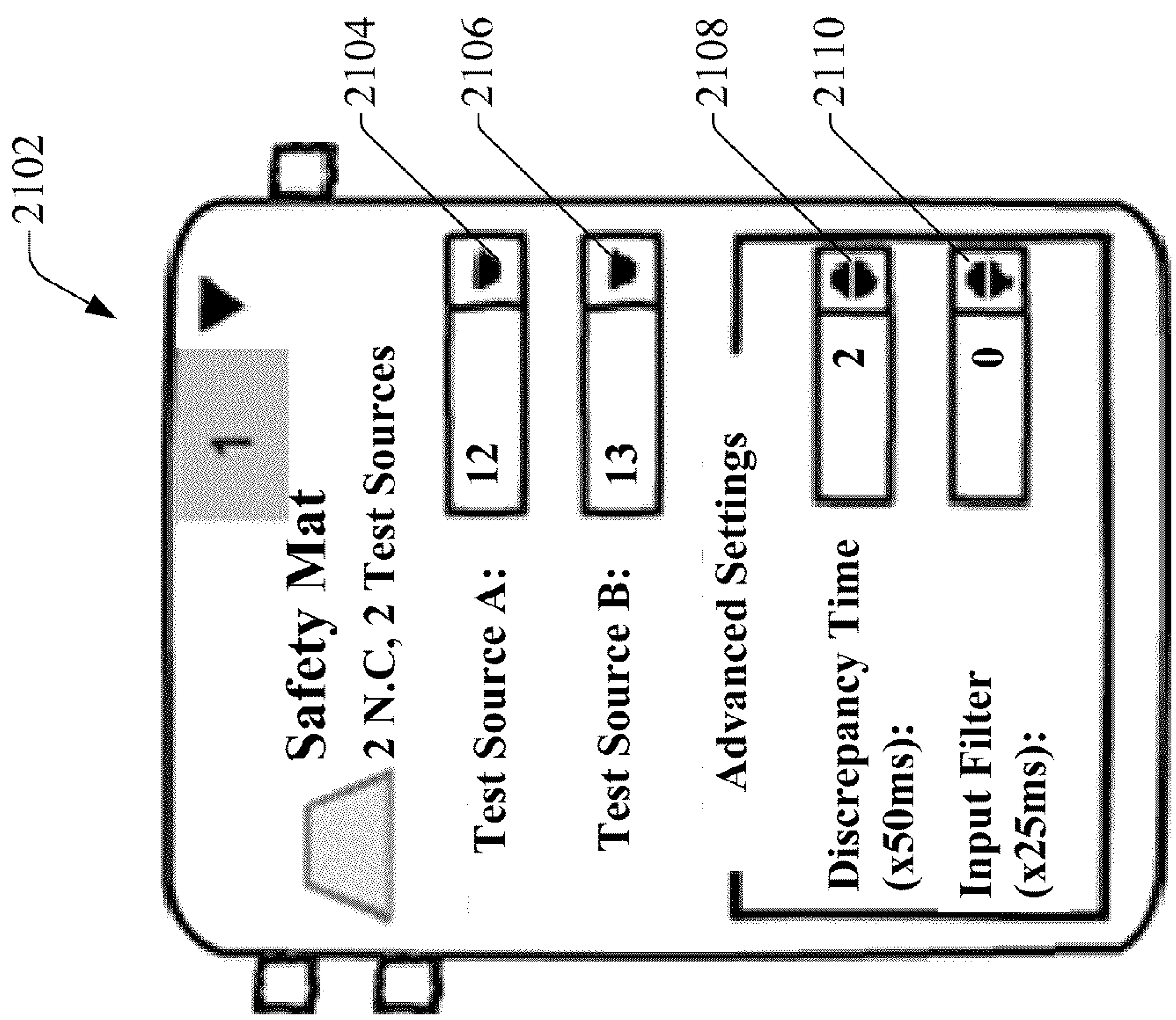

2102
2104
2106
2108
2110
1
Safety Mat
2 N.C, 2 Test Sources
Test Source A:
12
Test Source B:
13
Advanced Settings
Discrepancy Time
(x50ms):
2
Input Filter
(x25ms):
0

FIG. 21

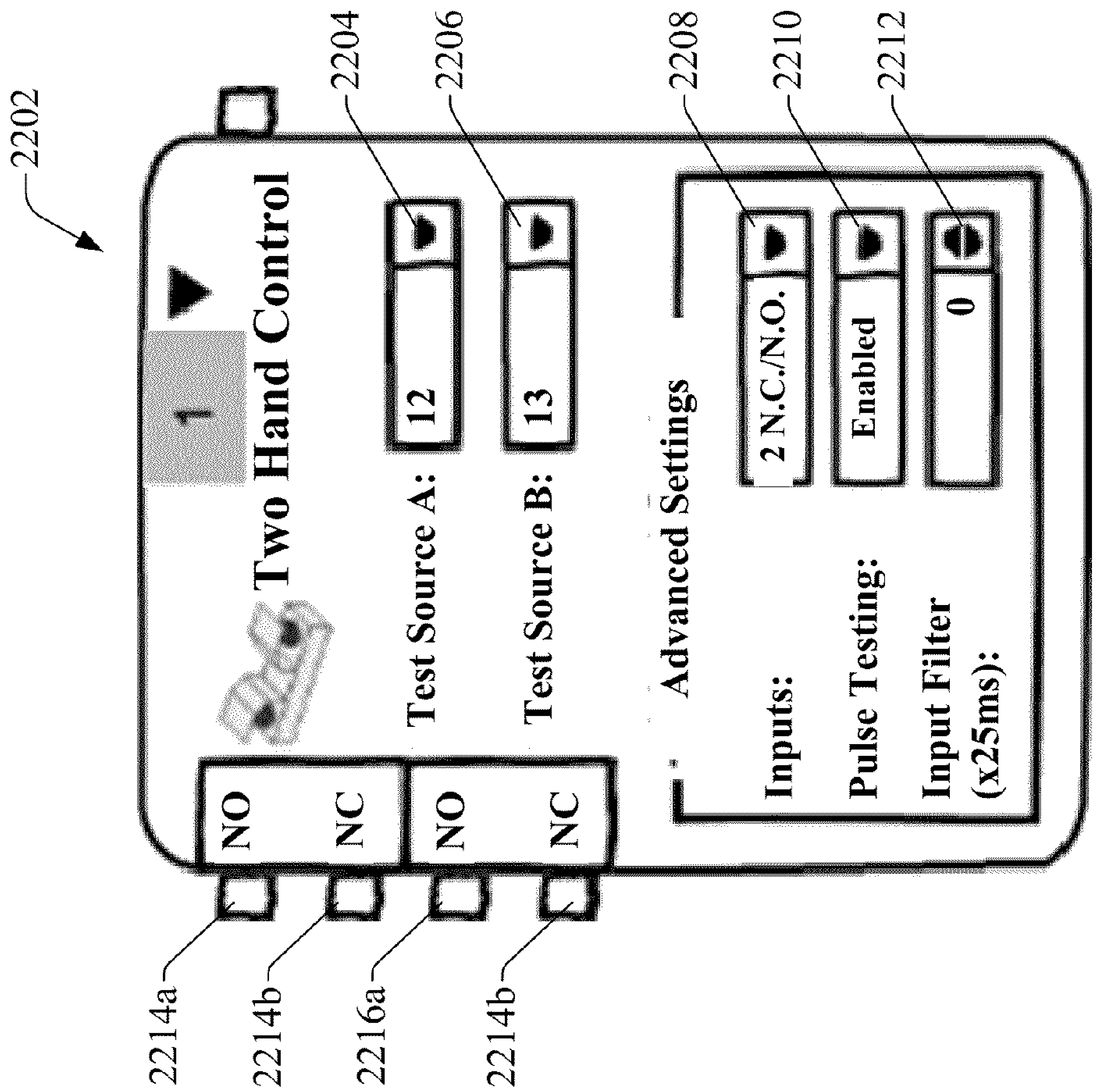

2202
2204
2206
2208
2210
2212
1
Two Hand Control
Test Source A:
12
Test Source B:
13
Advanced Settings
Inputs:
2 N.C./N.O.
Pulse Testing:
Enabled
Input Filter
(x25ms):
0
NO
NC
NO
NC
2214a
2214b
2216a
2214b

FIG. 22

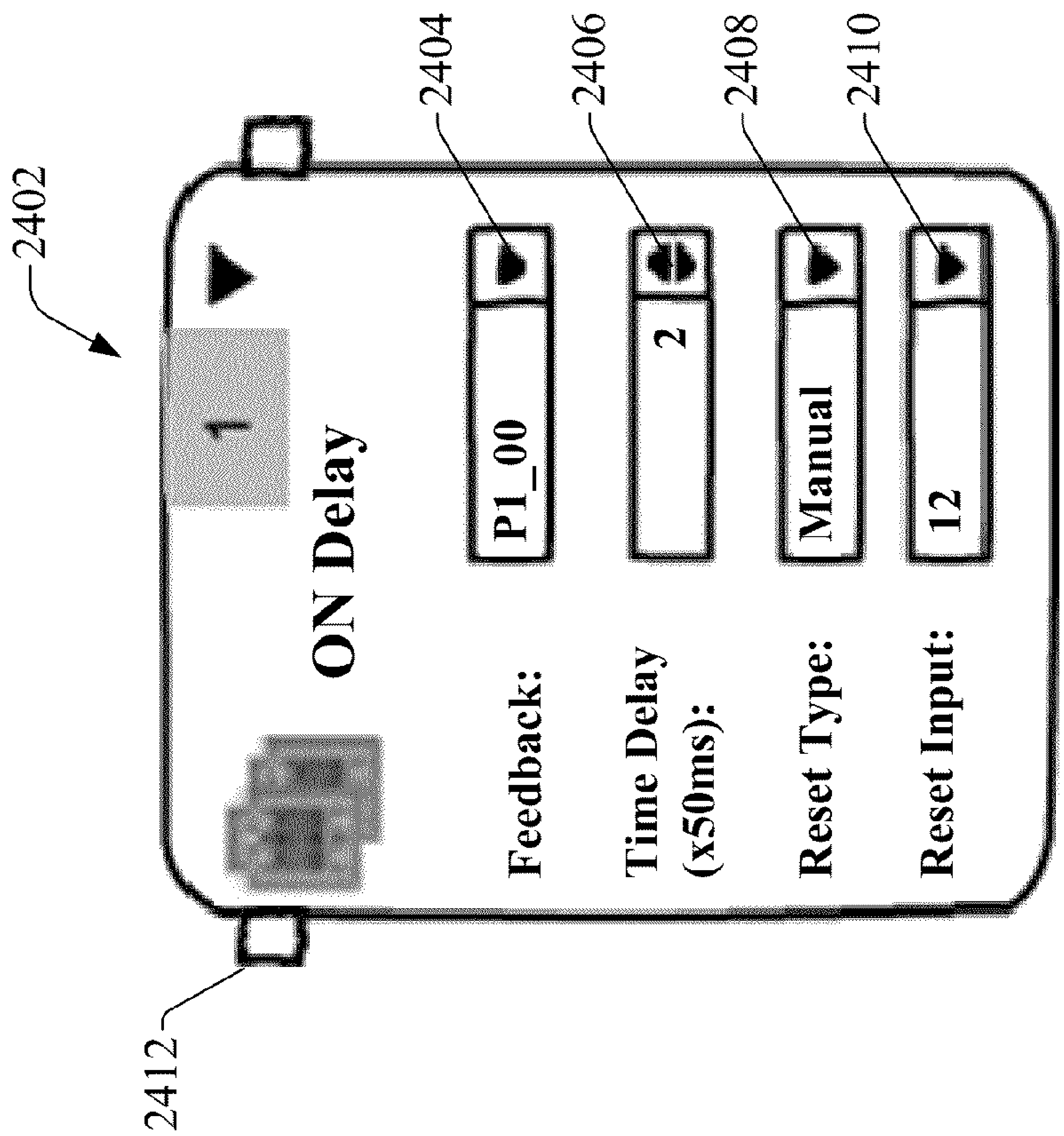

2402
2404
2406
2408
2410
2412
1
ON Delay
Feedback:
P1_00
Time Delay (x50ms):
2
Reset Type:
Manual
Reset Input:
12

FIG. 24

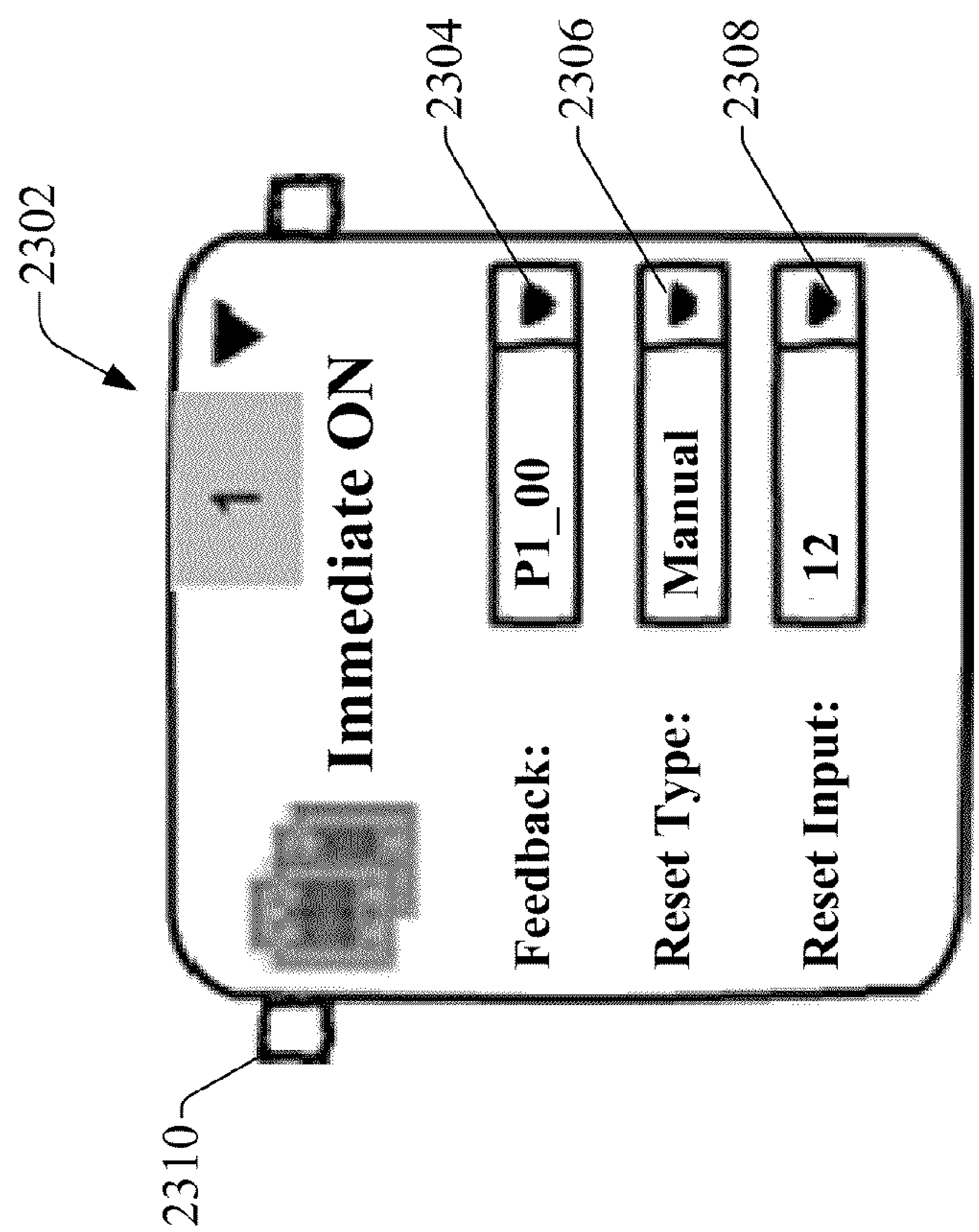

2302
2304
2306
2308
2310
1
Immediate ON
Feedback:
P1_00
Reset Type:
Manual
Reset Input:
12

FIG. 23

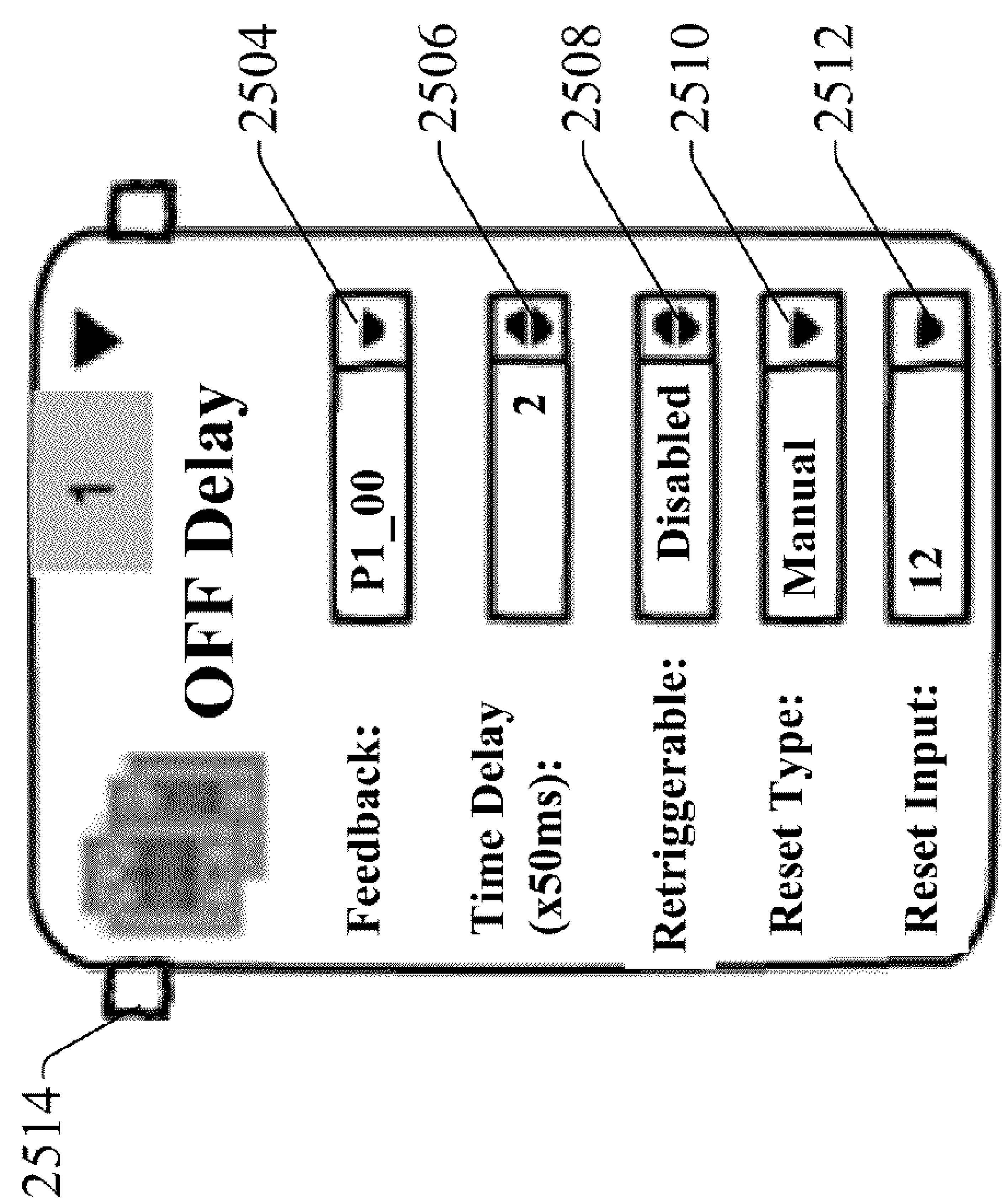

2502
2504
2506
2508
2510
2512
2514
1
OFF Delay
Feedback:
P1_00
Time Delay (x50ms):
2
Retriggerable:
Disabled
Reset Type:
Manual
Reset Input:
12

FIG. 25

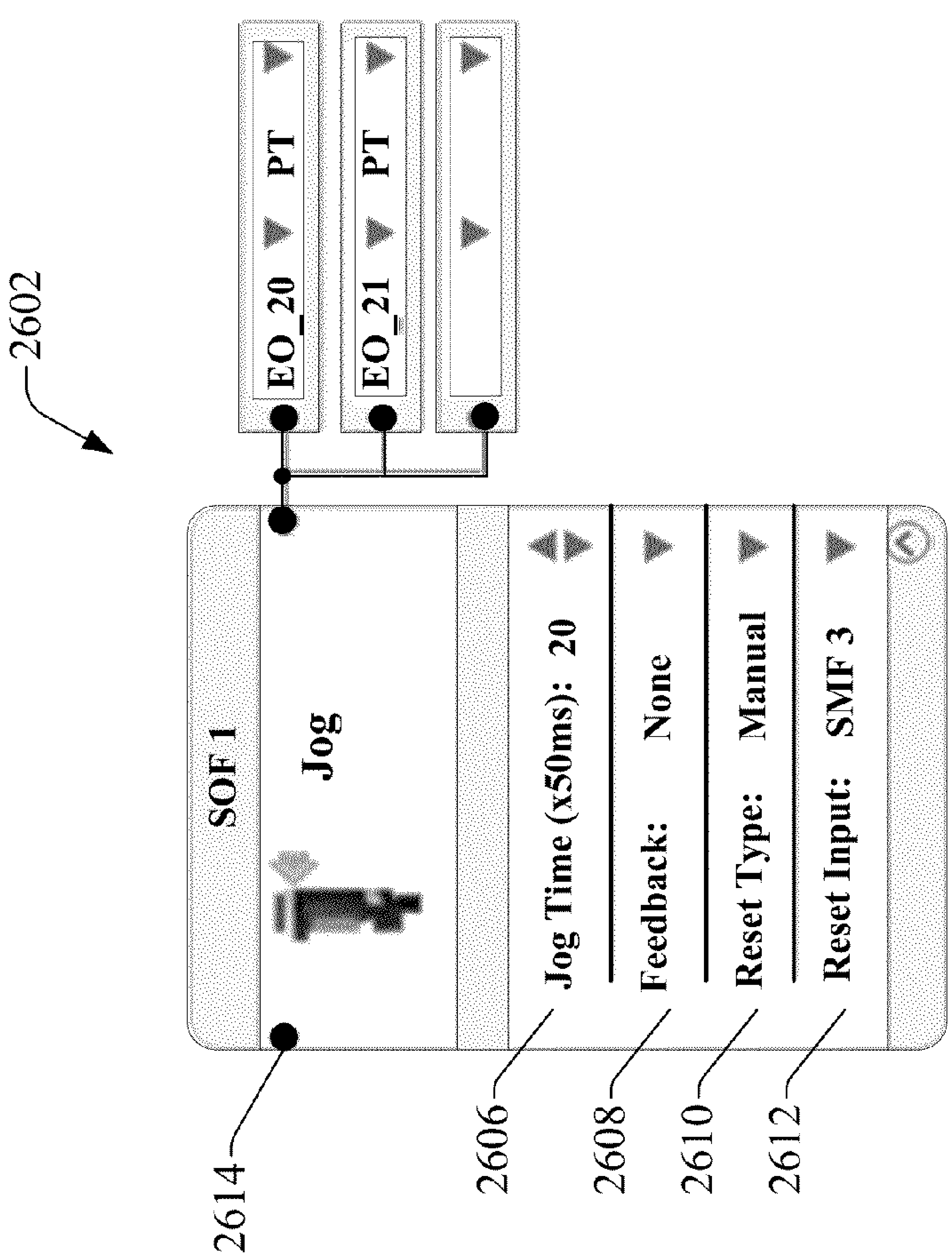

2602
EO_20
PT
EO_21
PT
SOF 1
Jog
Jog Time (x50ms): 20
Feedback: None
Reset Type: Manual
Reset Input: SMF 3
2606
2608
2610
2612
2614

FIG. 26

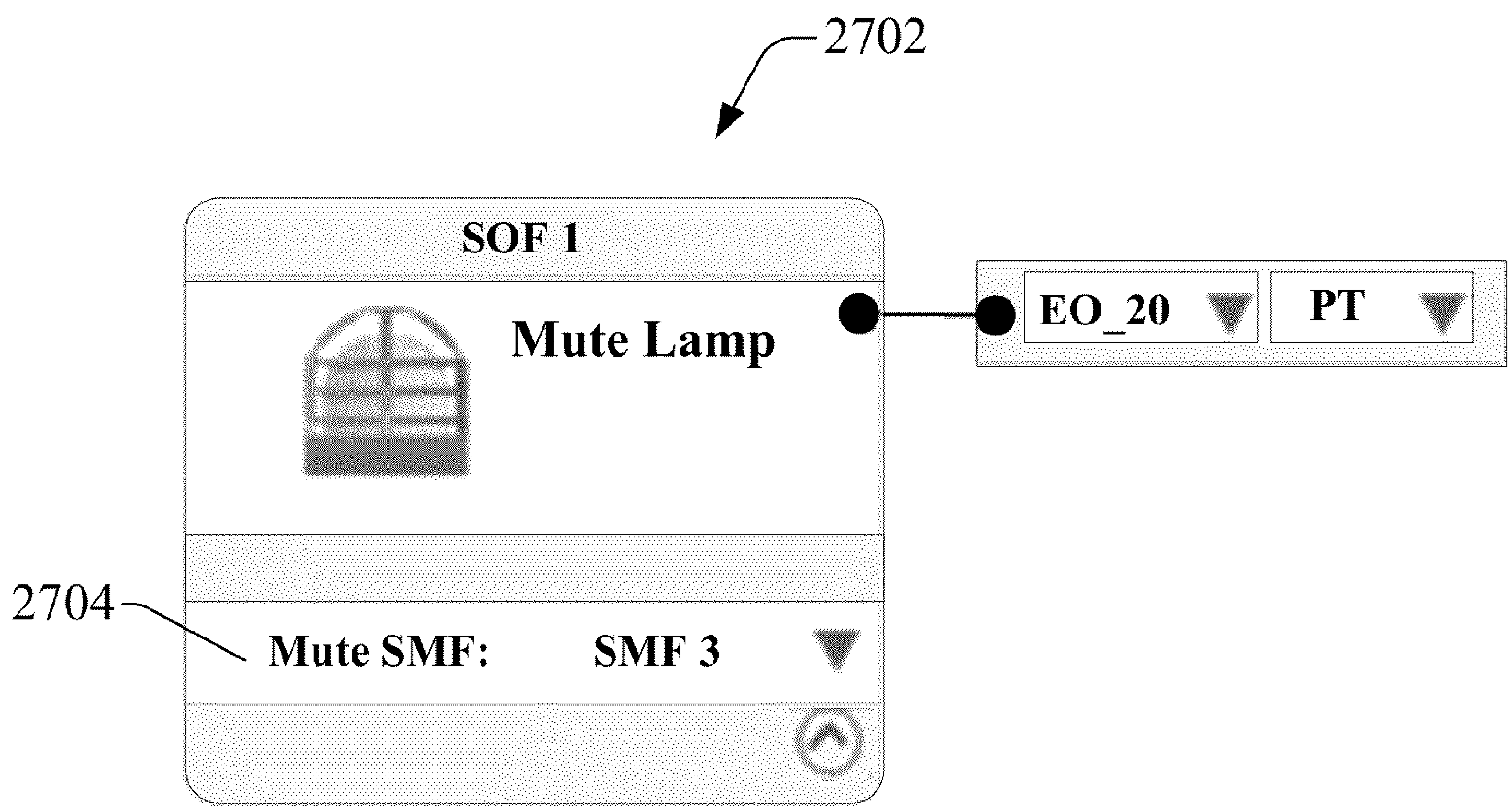


FIG. 27a

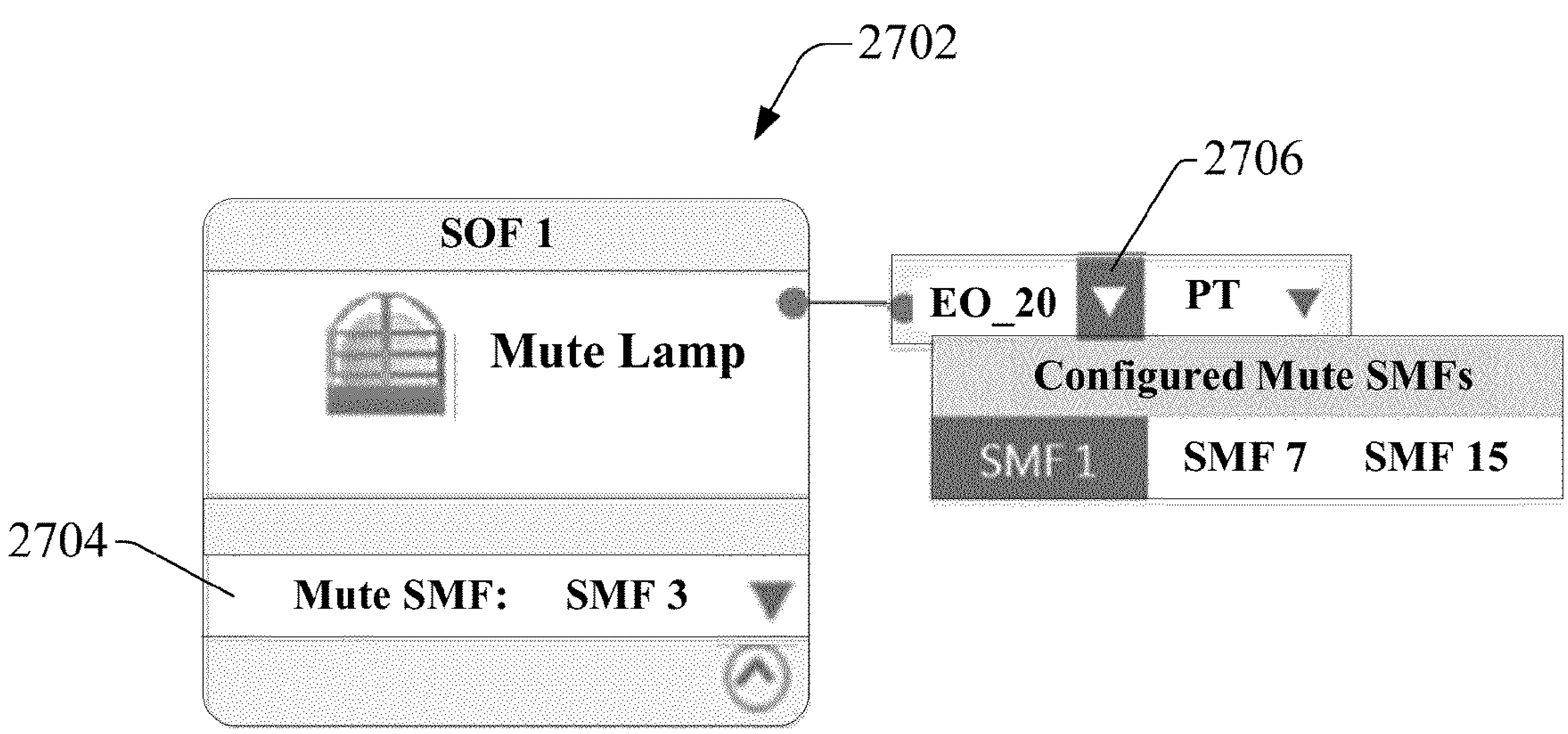
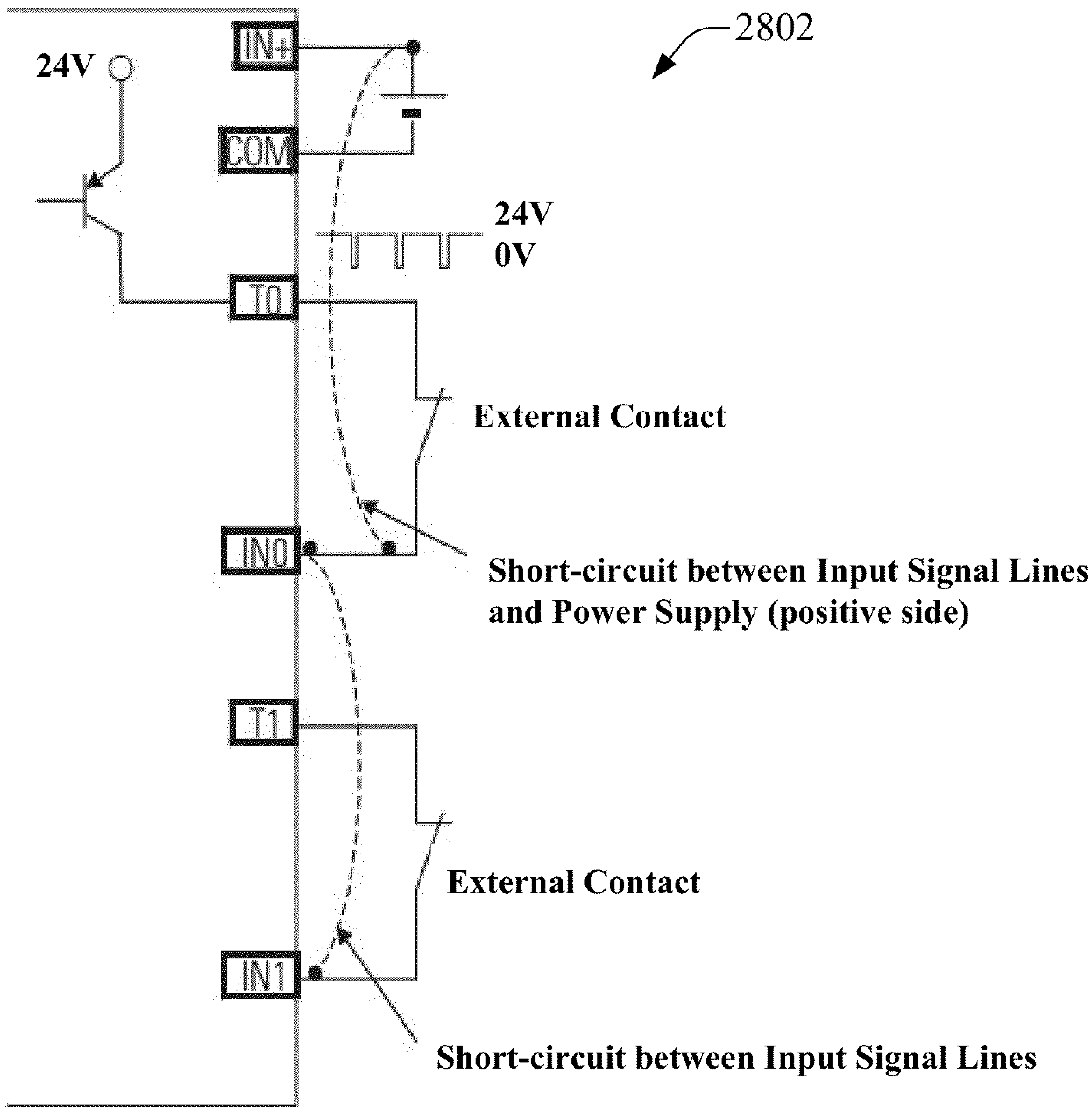
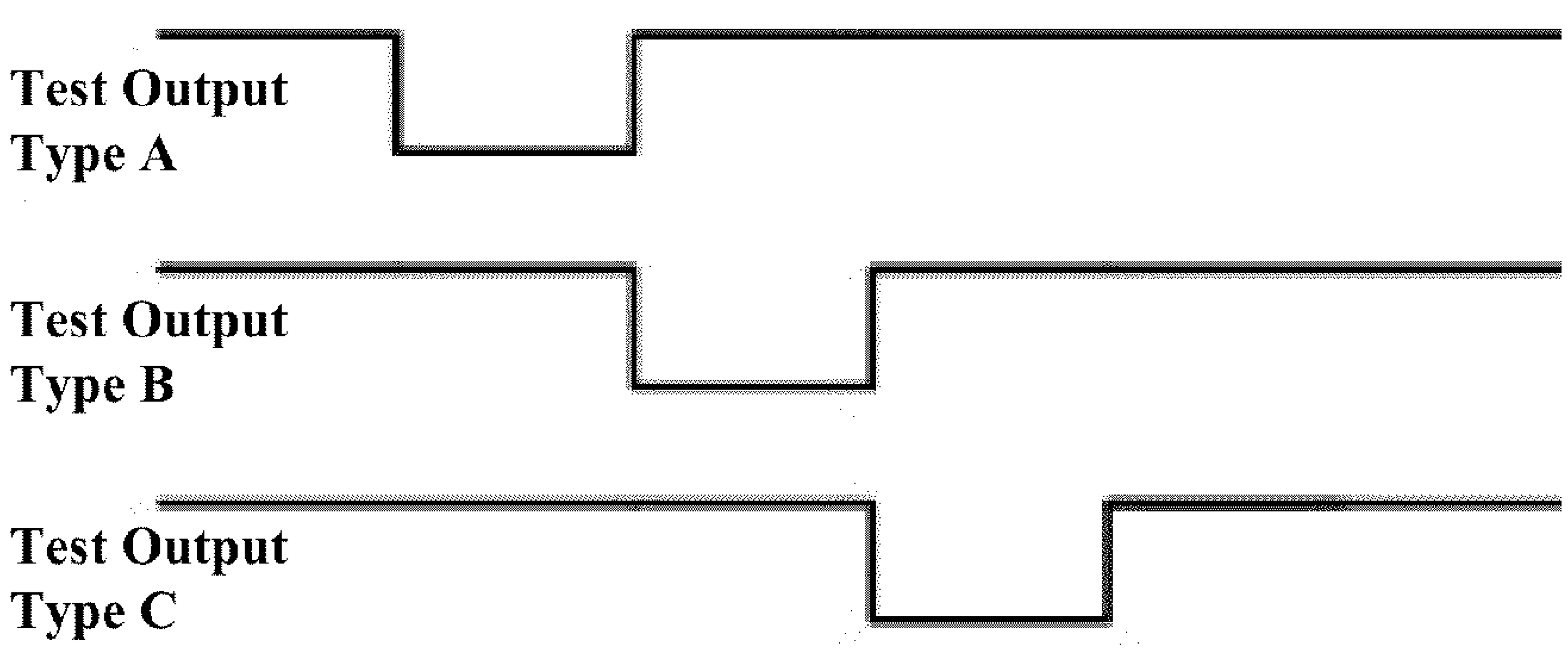


FIG. 27b



2802
24V
IN+
COM
24V
0V
T0
External Contact
IN0
Short-circuit between Input Signal Lines and Power Supply (positive side)
T1
External Contact
IN1
Short-circuit between Input Signal Lines

FIG. 28



Test Output Type A
Test Output Type B
Test Output Type C

FIG. 29

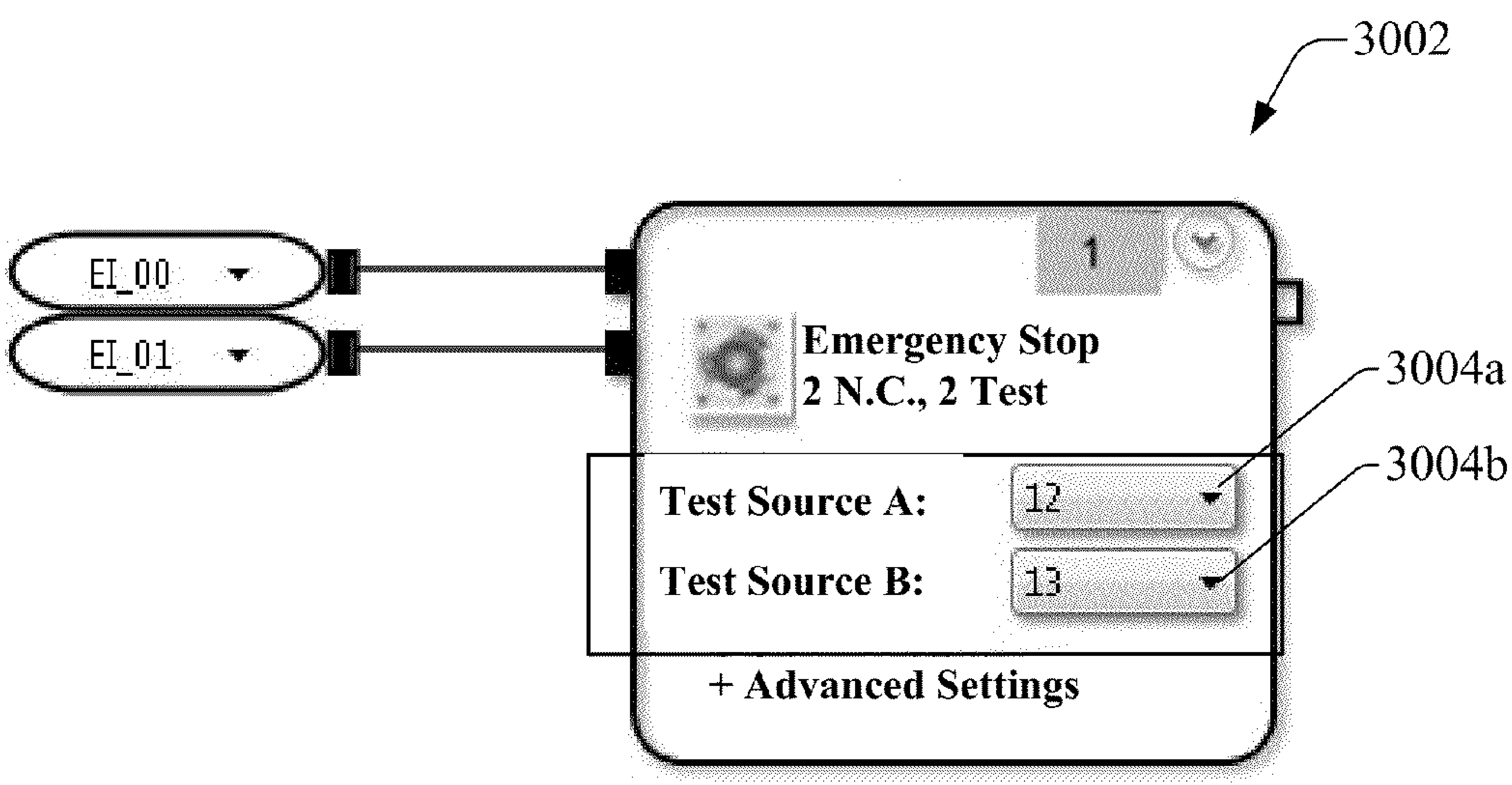


FIG. 30a

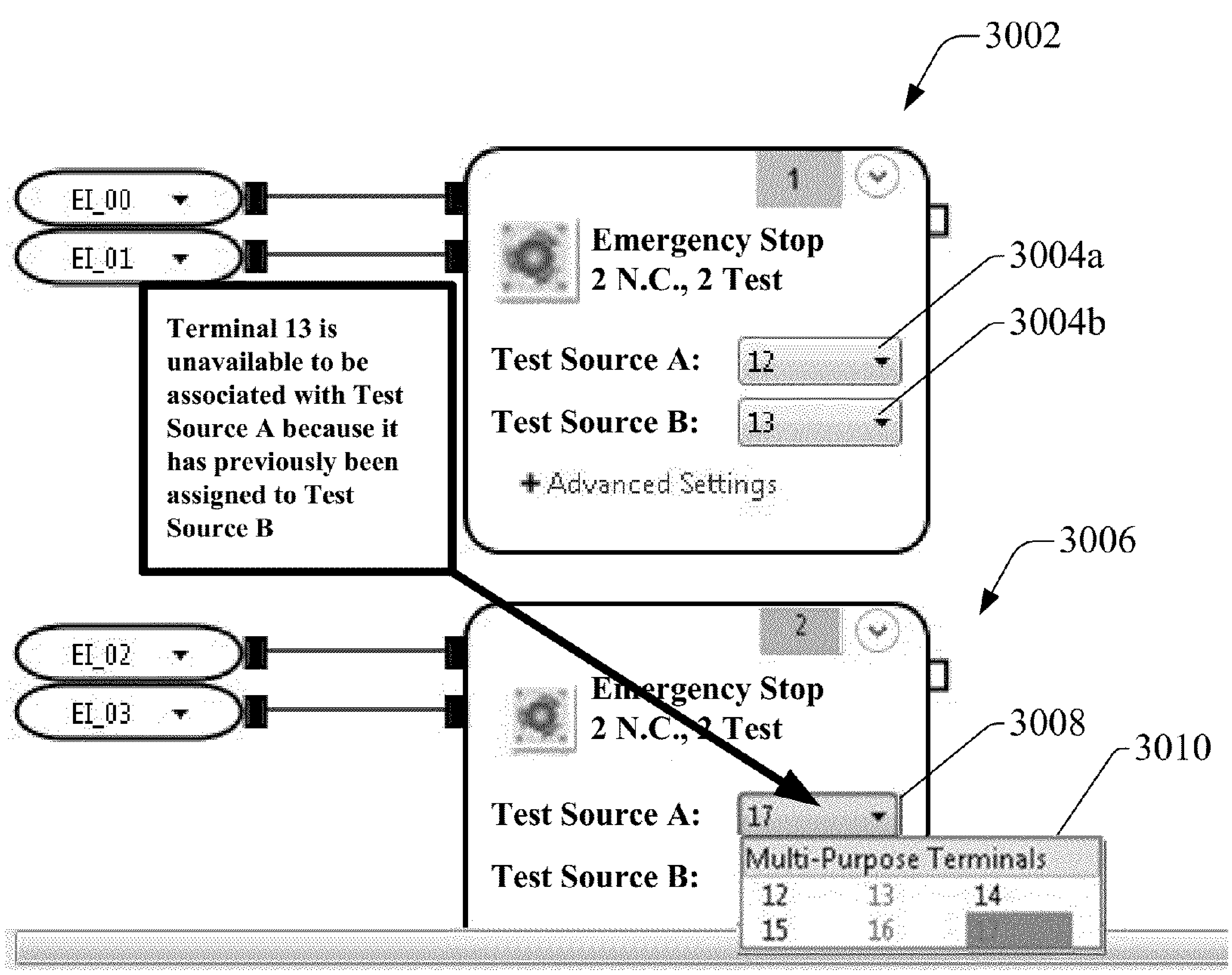


FIG. 30b

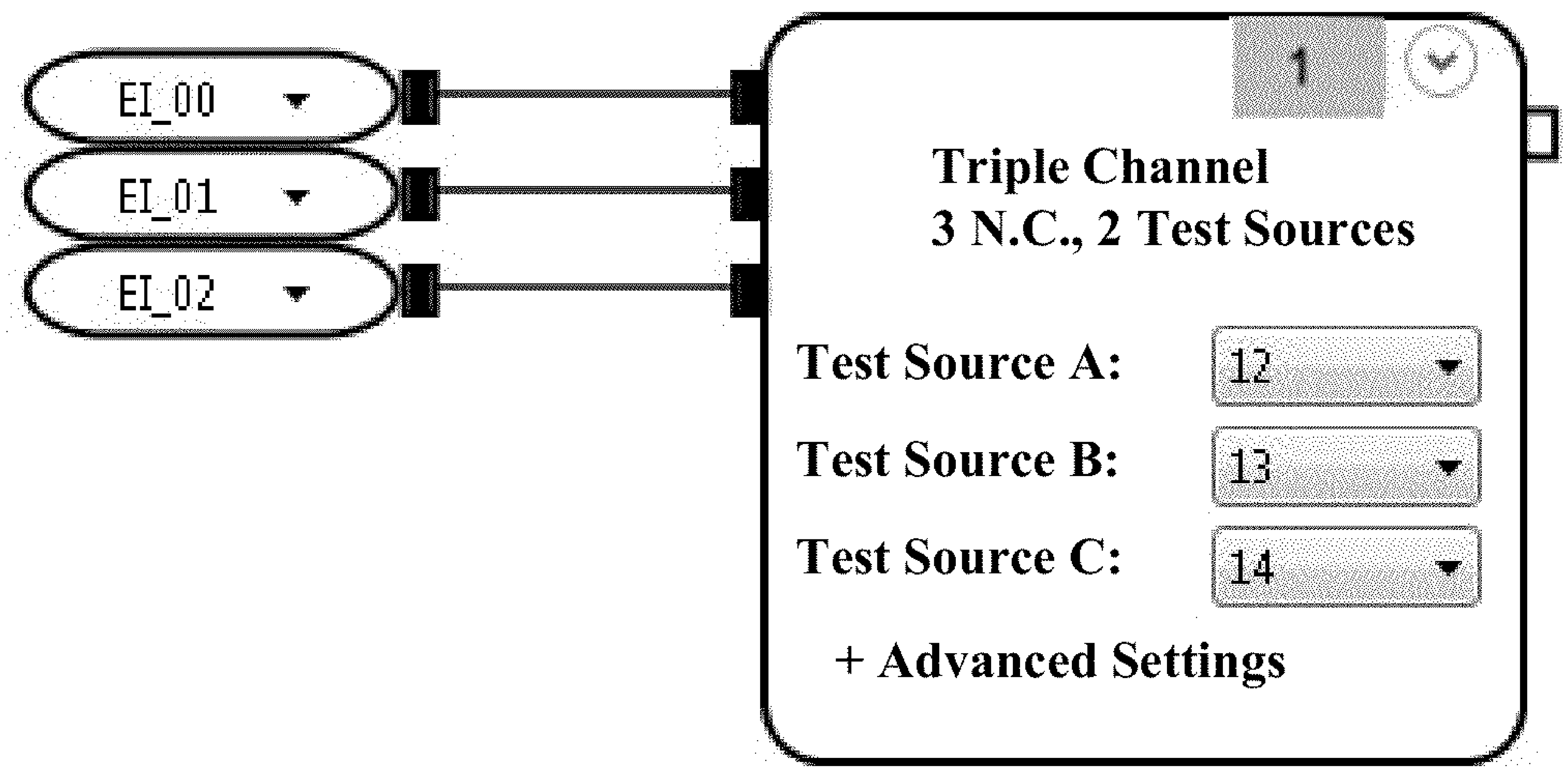

EI_00
EI_01
EI_02
1
Triple Channel
3 N.C., 2 Test Sources
Test Source A:
12
Test Source B:
13
Test Source C:
14
+ Advanced Settings

FIG. 30c

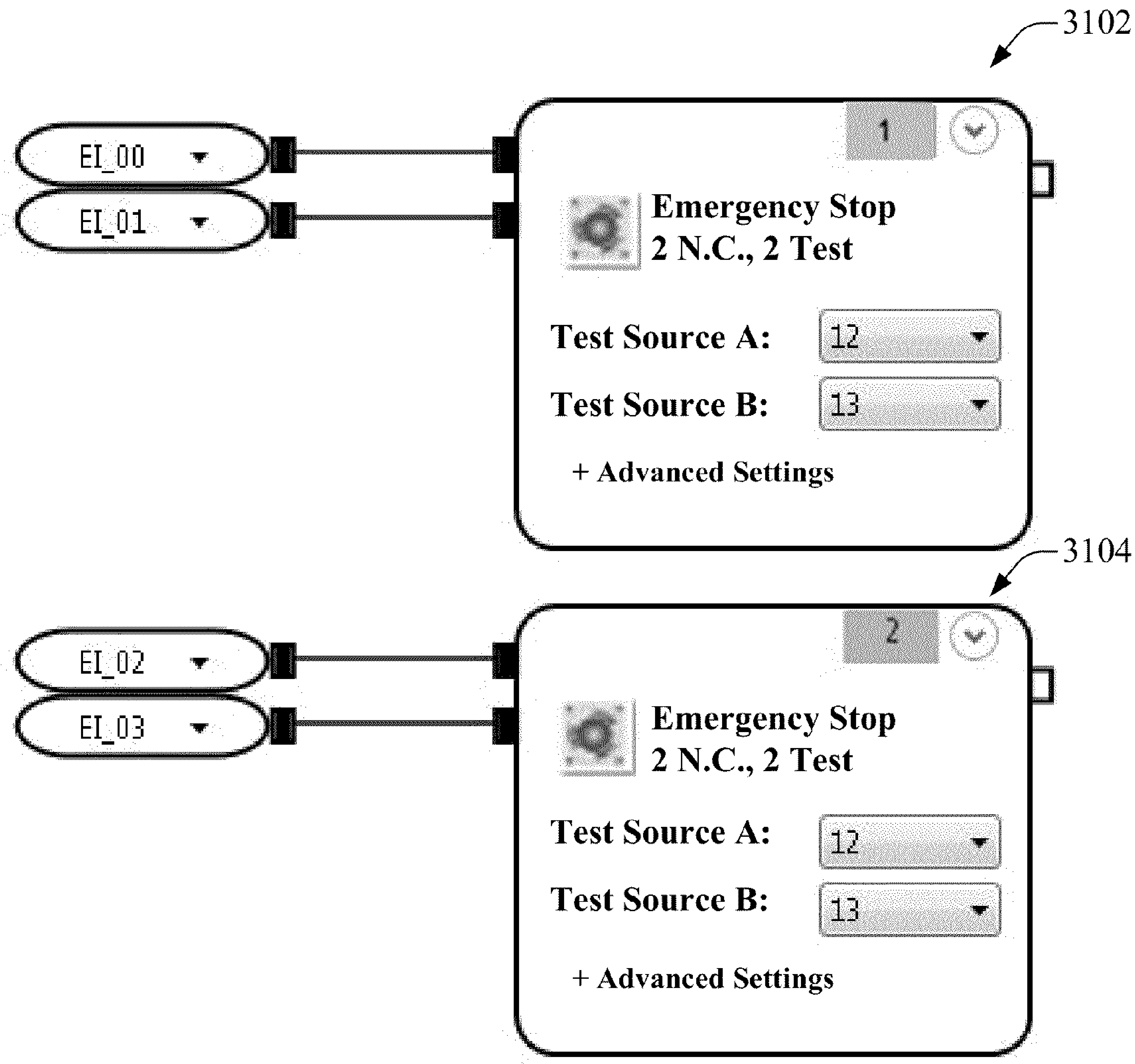

3102
EI_00
EI_01
1
Emergency Stop
2 N.C., 2 Test
Test Source A:
12
Test Source B:
13
+ Advanced Settings
3104
EI_02
EI_03
2
Emergency Stop
2 N.C., 2 Test
Test Source A:
12
Test Source B:
13
+ Advanced Settings

FIG. 31

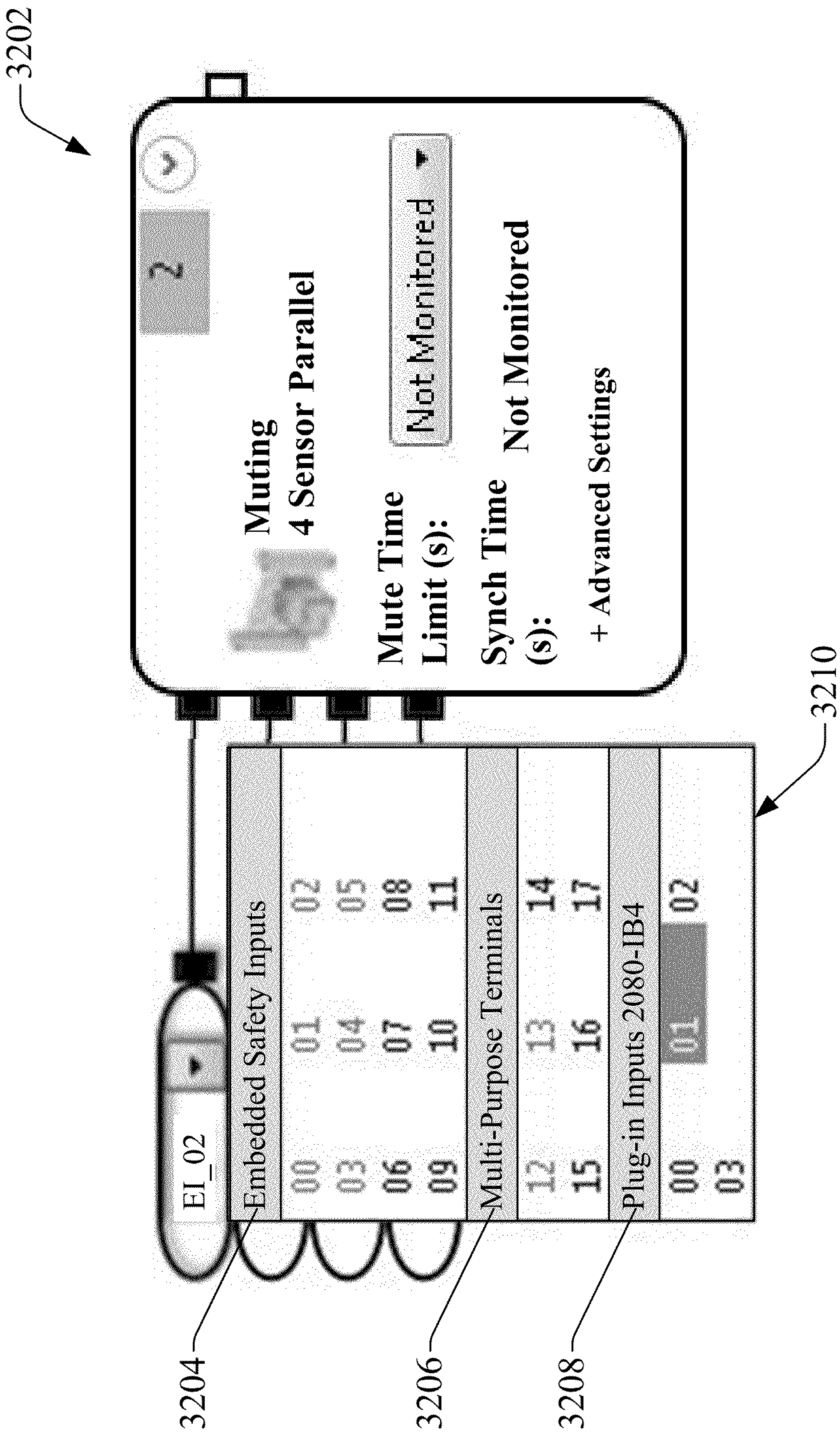

3202
2
Muting
4 Sensor Parallel
Mute Time Limit (s):
Not Monitored
Synch Time (s):
Not Monitored
+ Advanced Settings
EI_02
Embedded Safety Inputs
00 01 02
03 04 05
06 07 08
09 10 11
Multi-Purpose Terminals
12 13 14
15 16 17
Plug-in Inputs 2080-IB4
00 01 02
03
3204
3206
3208
3210

FIG. 32

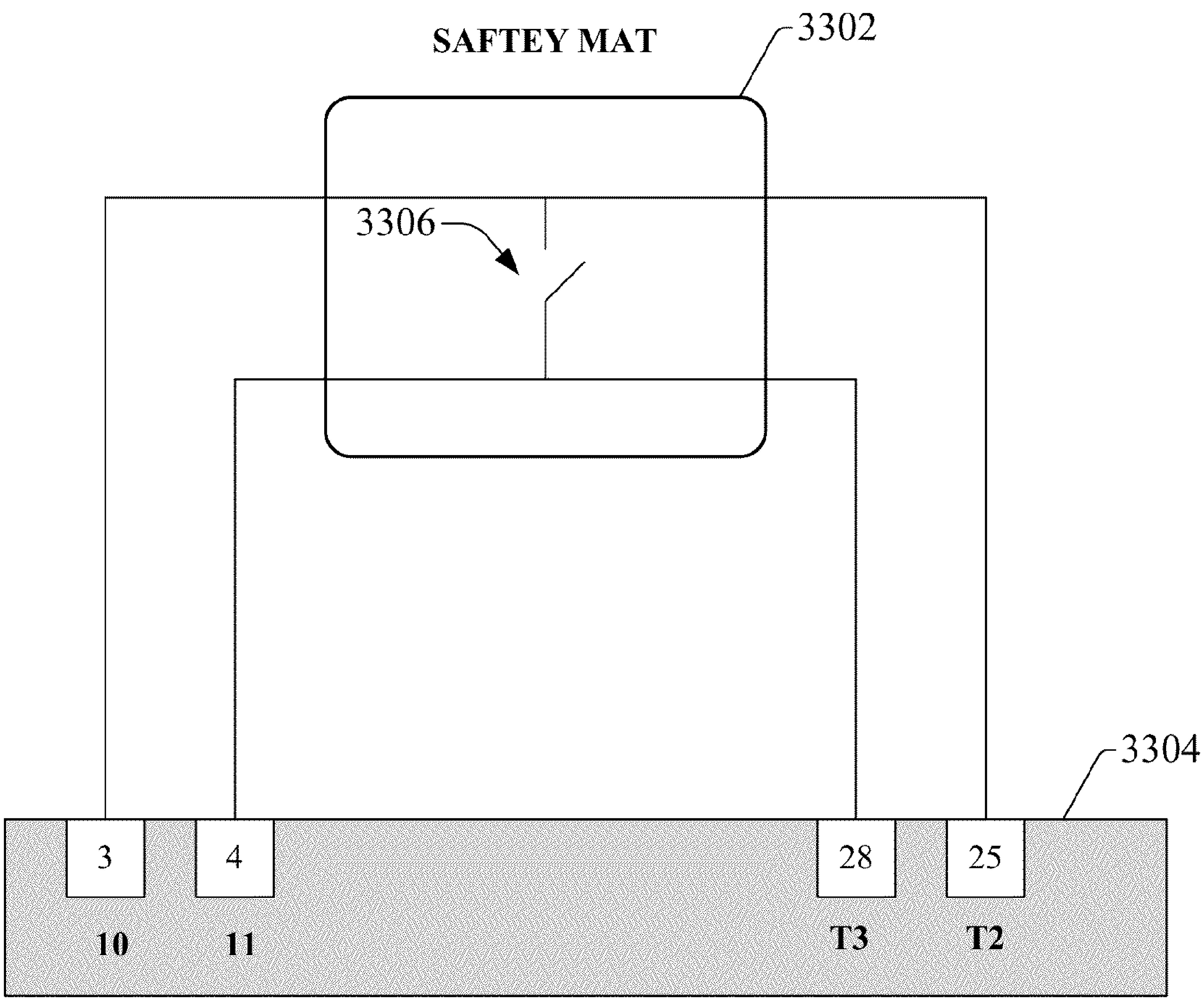


FIG. 33

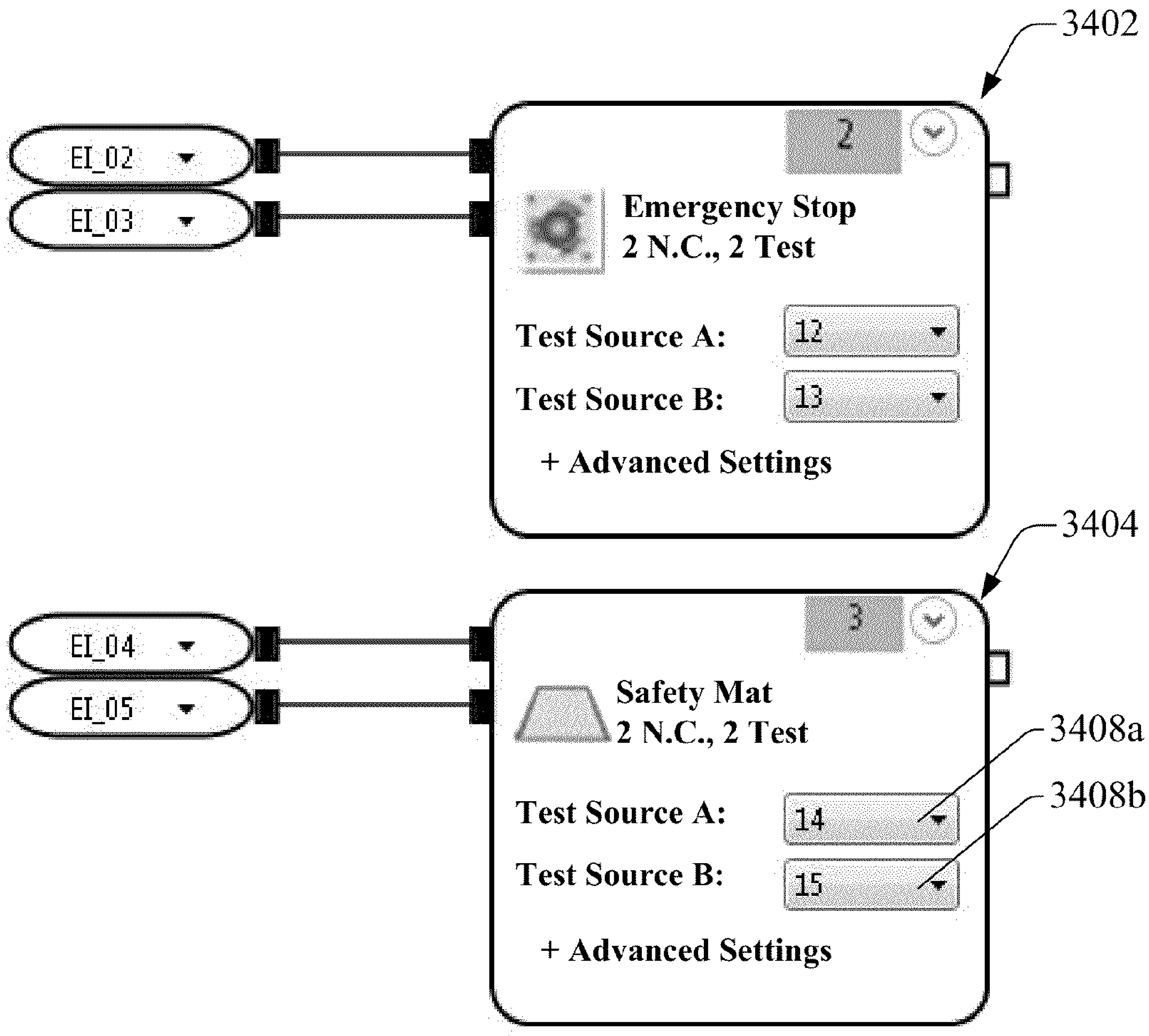

3402
EI_02
EI_03
2
Emergency Stop
2 N.C., 2 Test
Test Source A:
12
Test Source B:
13
+ Advanced Settings
3404
EI_04
EI_05
3
Safety Mat
2 N.C., 2 Test
3408a
3408b
Test Source A:
14
Test Source B:
15
+ Advanced Settings

FIG. 34

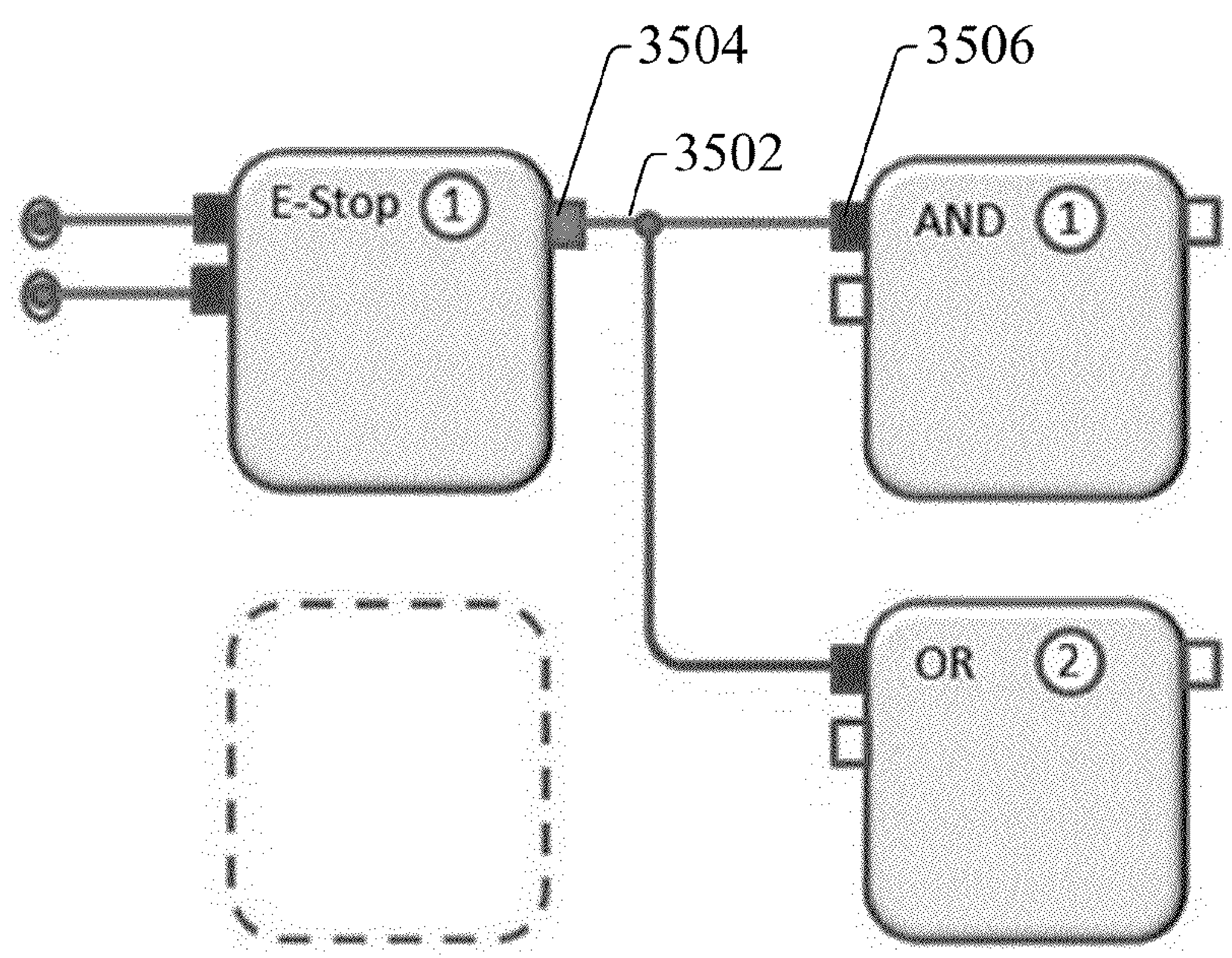

3504
3506
3502
E-Stop 1
AND 1
OR 2

FIG. 35

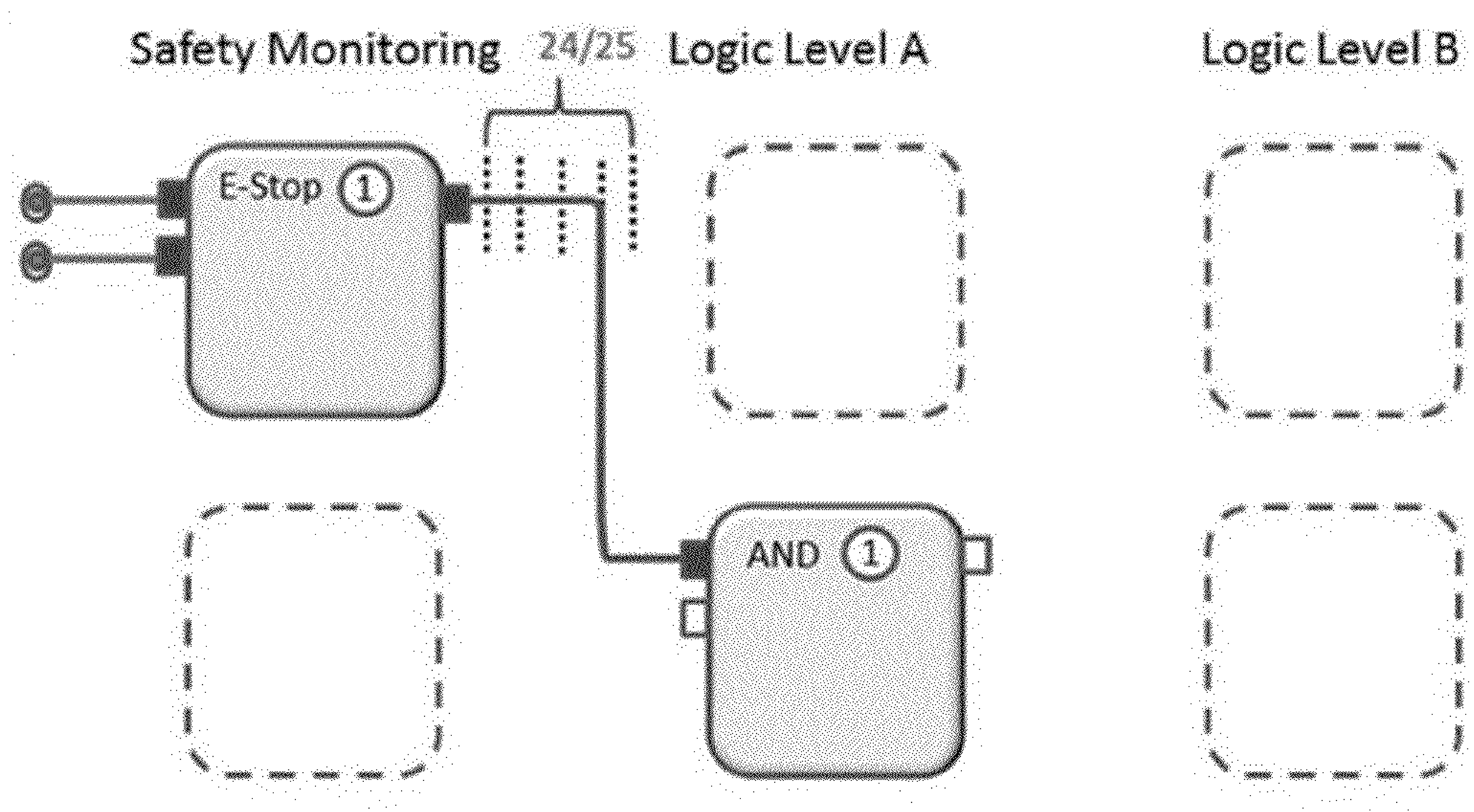

Safety Monitoring
24/25
Logic Level A
Logic Level B
E-Stop 1
AND 1

FIG. 36

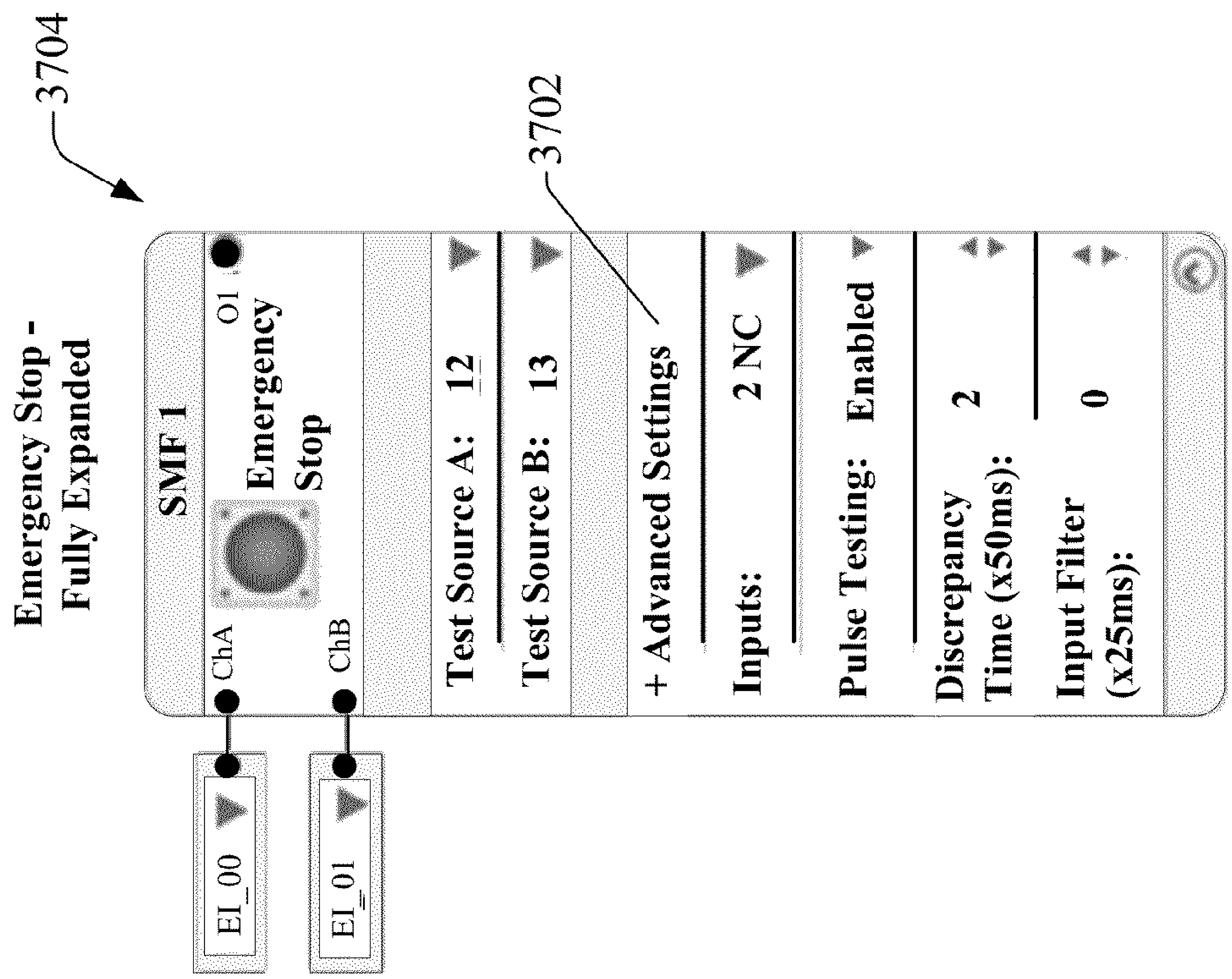


FIG. 37b

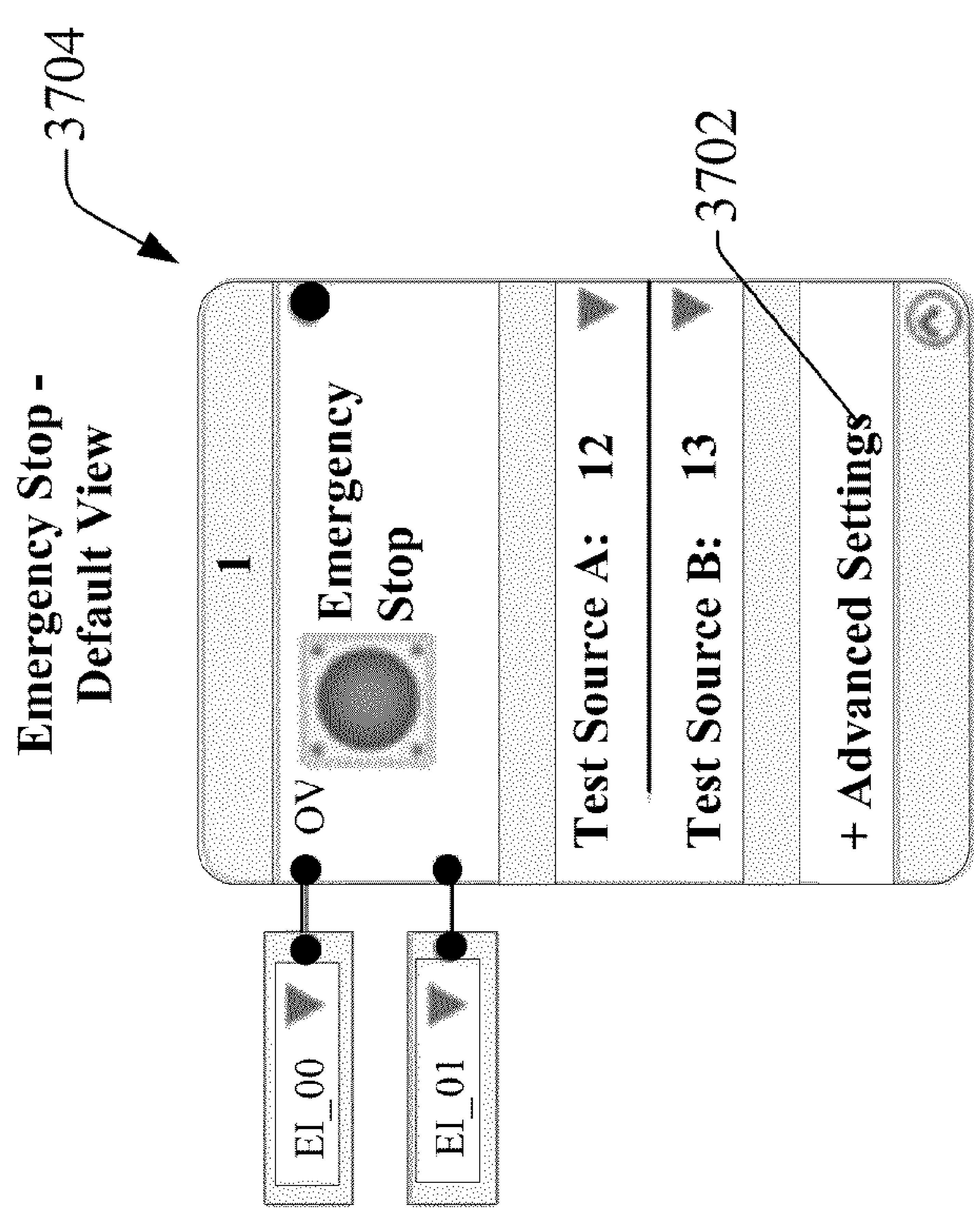


FIG. 37a

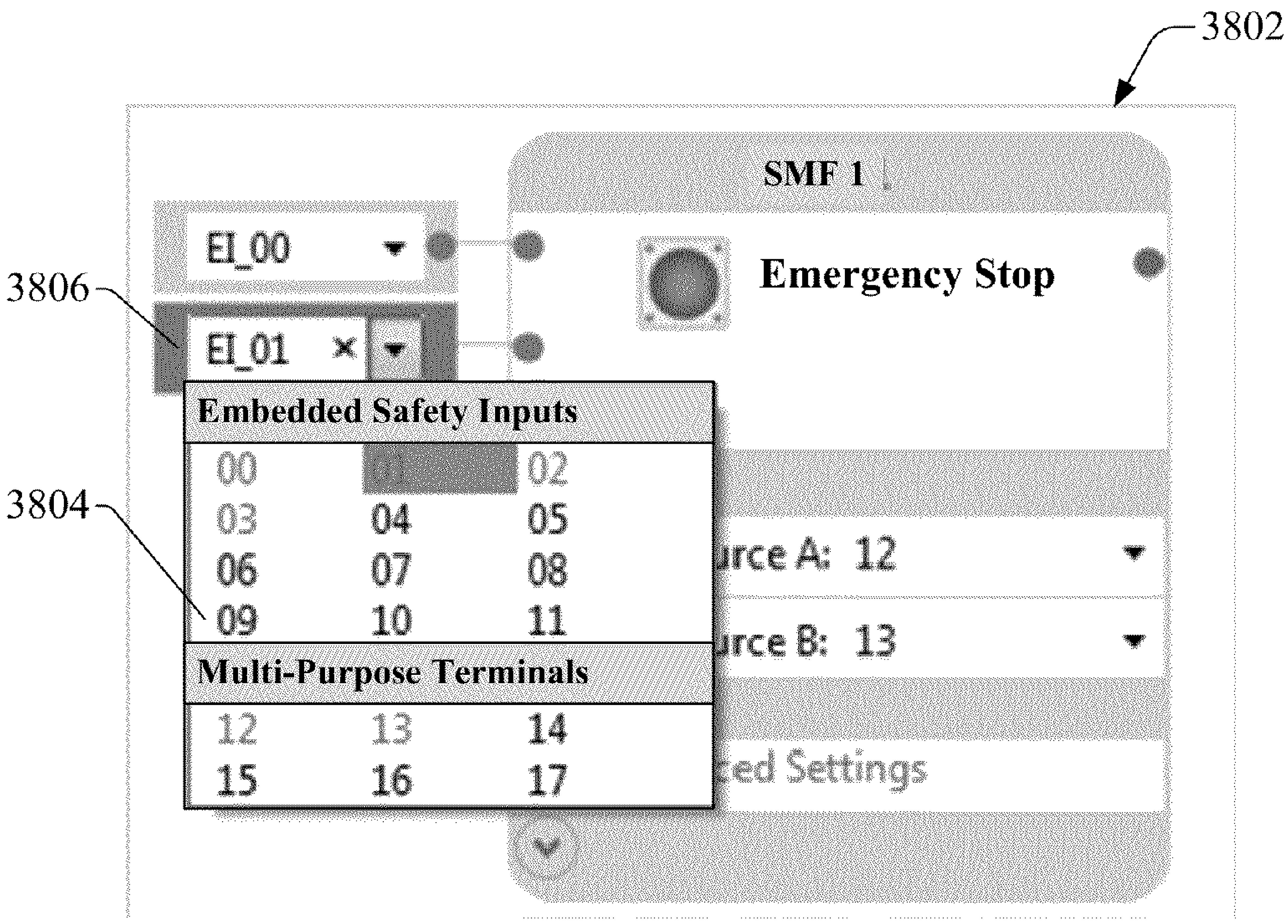


FIG. 38a

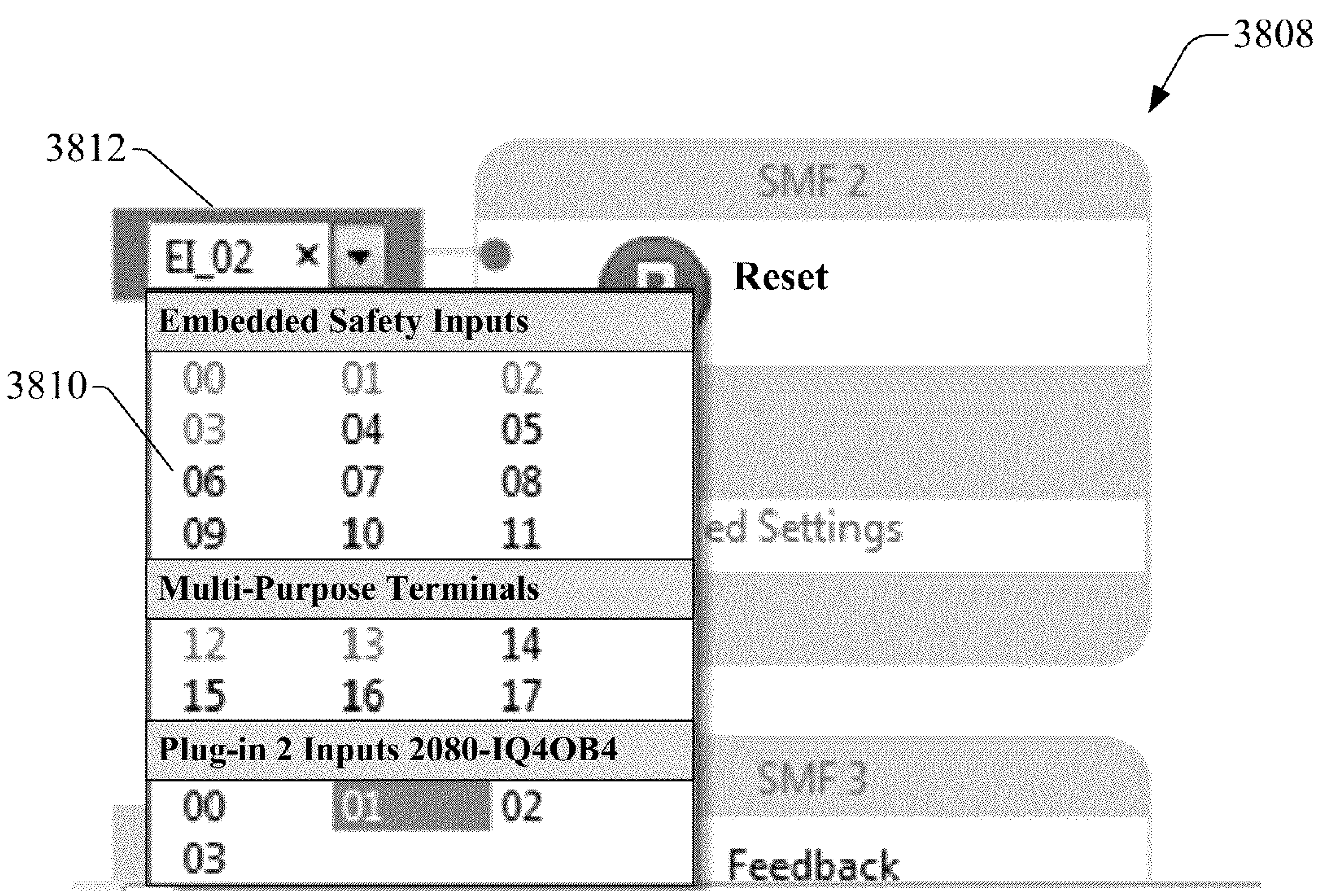


FIG. 38b

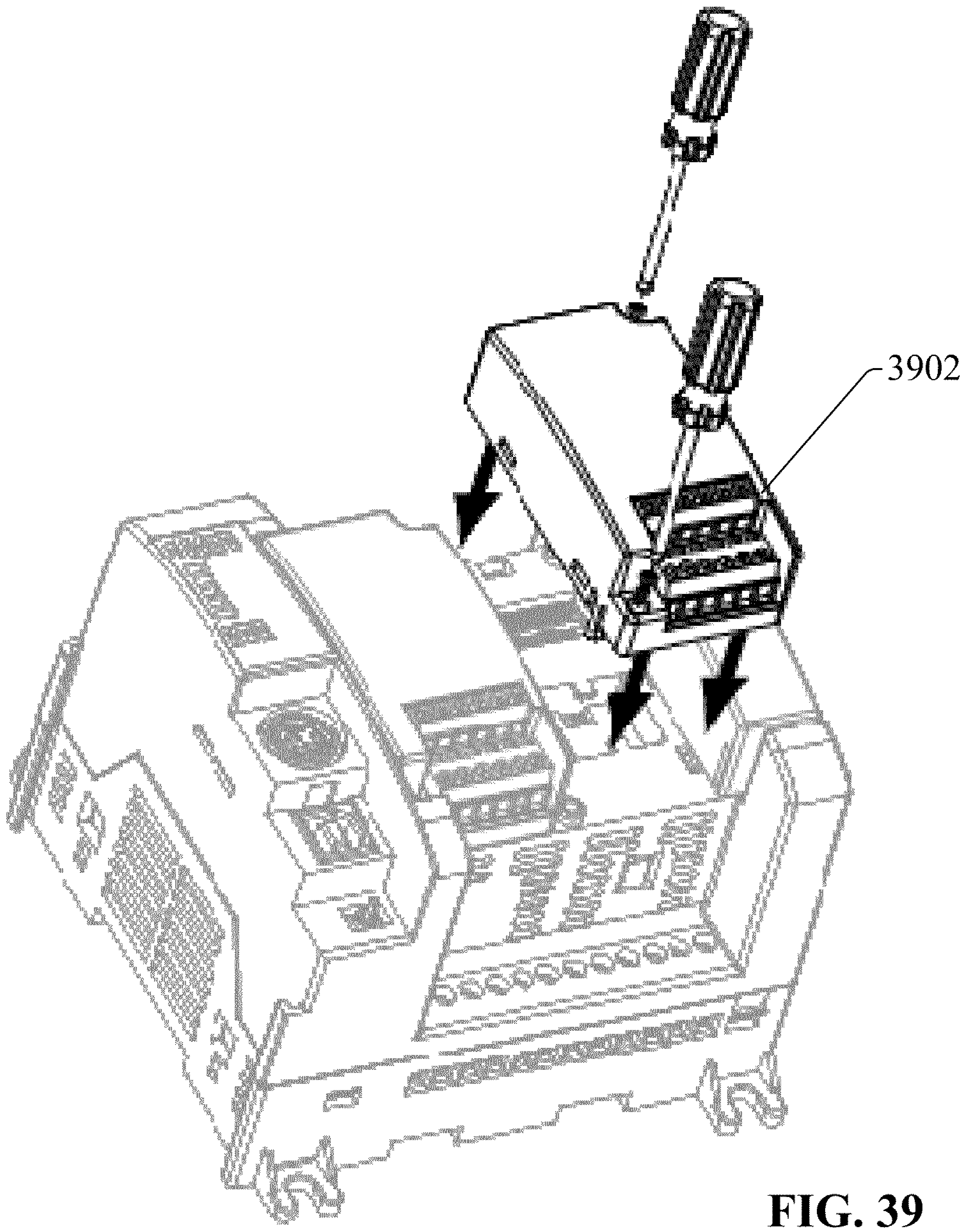


FIG. 39

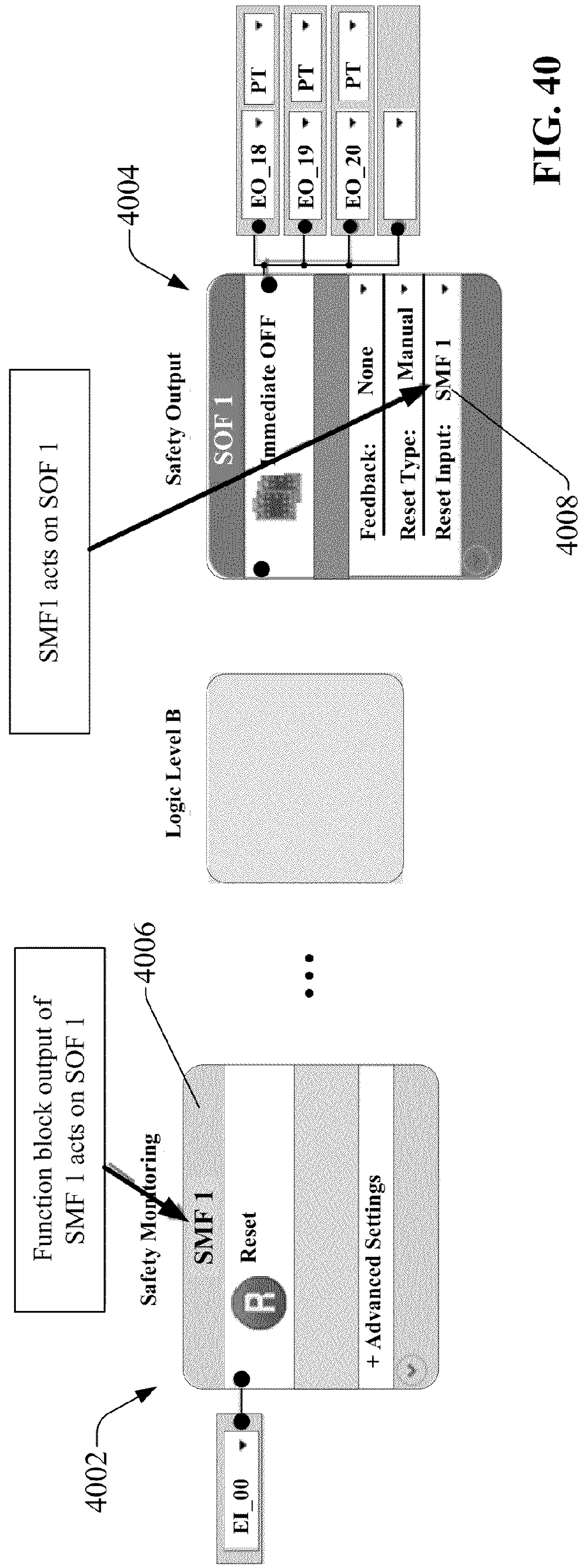

4002
EI_00
Safety Monitoring
SMF 1
Reset
R
+ Advanced Settings
4006
Function block output of SMF 1 acts on SOF 1
Logic Level B
SMF1 acts on SOF 1
4004
Safety Output
SOF 1
Immediate OFF
Feedback: None
Reset Type: Manual
Reset Input: SMF 1
4008
EO_18
EO_19
EO_20
PT
PT
PT

FIG. 40

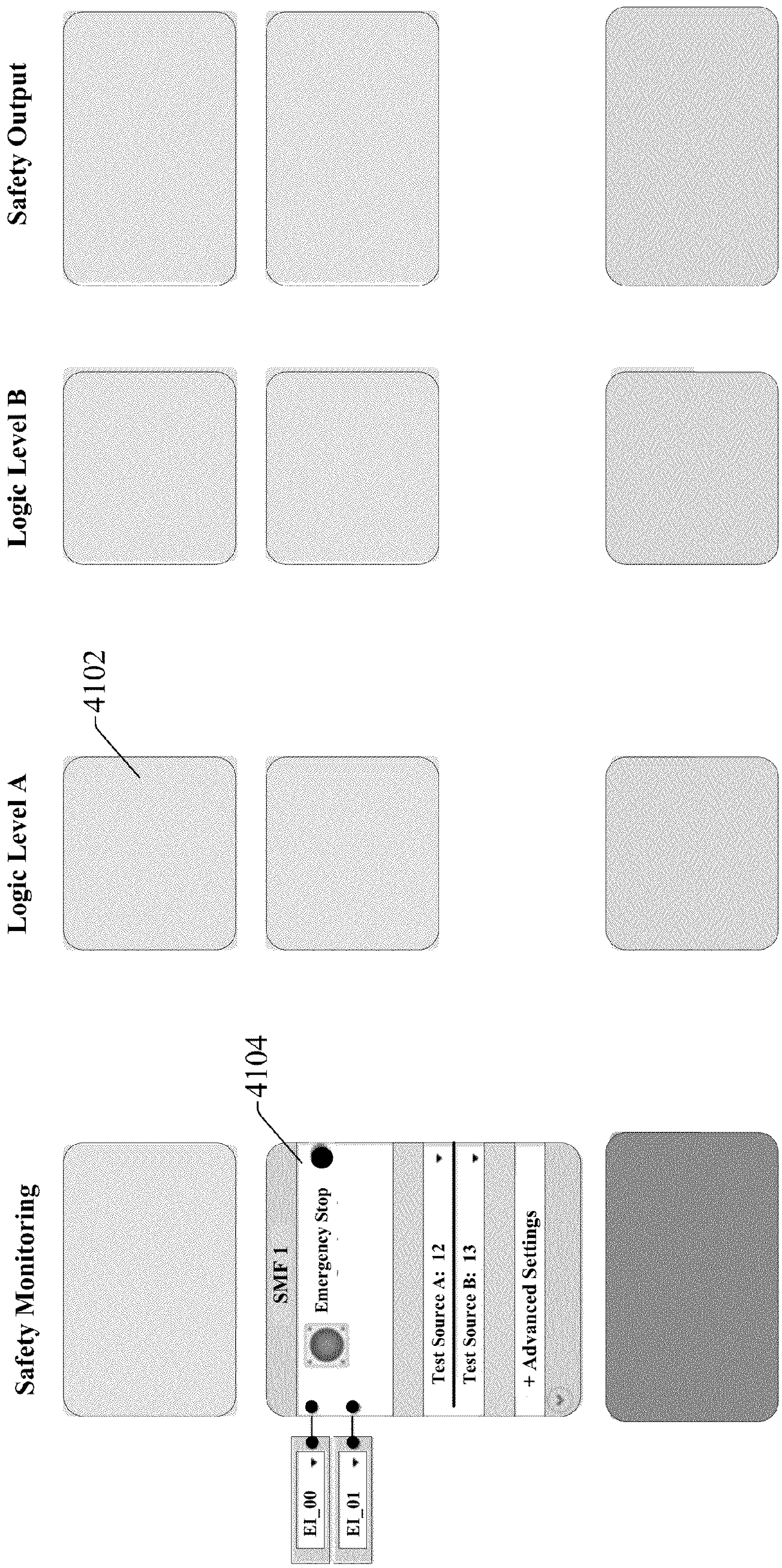
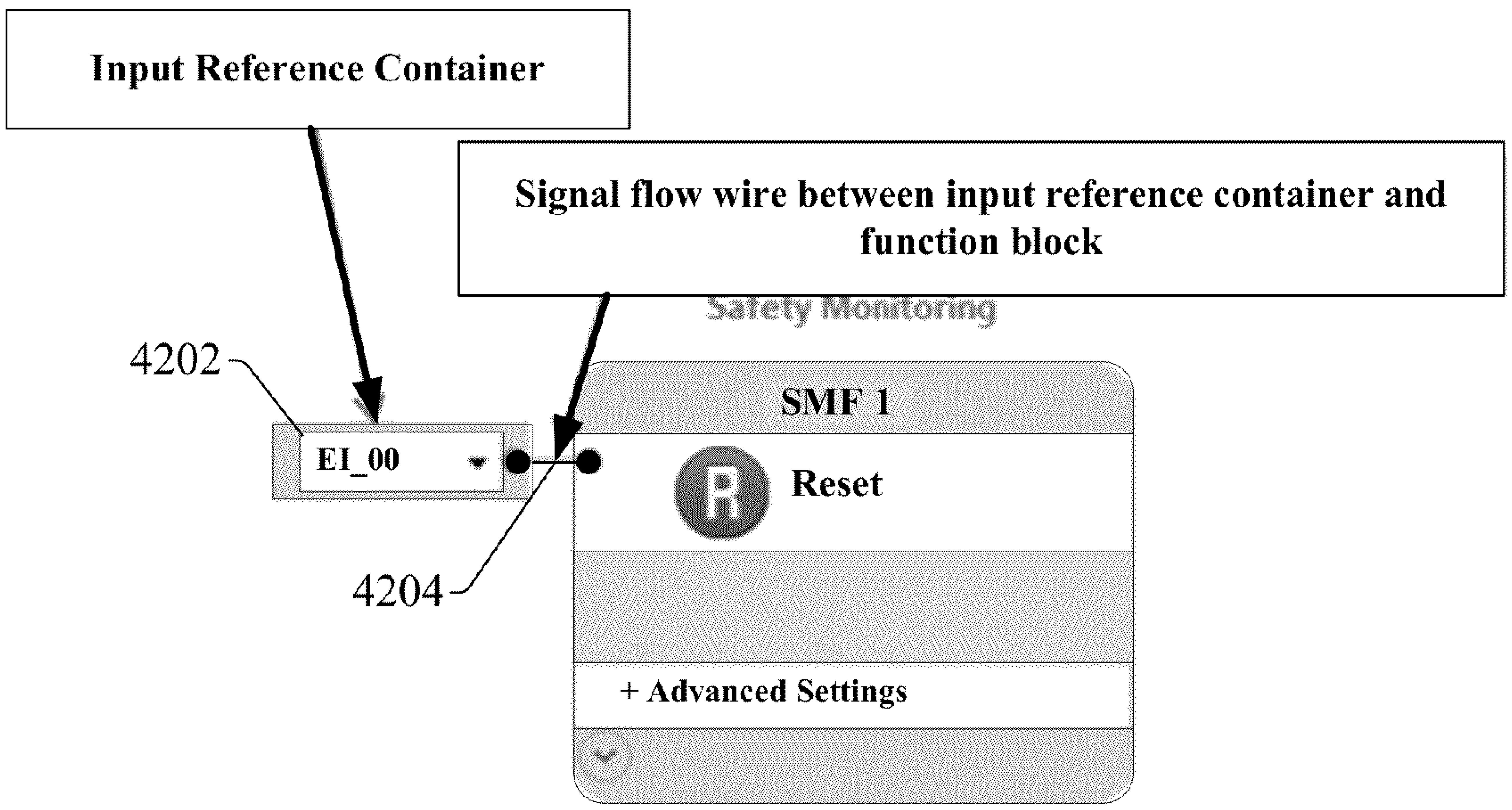

Safety Monitoring
Logic Level A
Logic Level B
Safety Output
4102
4104
SMF 1
Emergency Stop
Test Source A: 12
Test Source B: 13
+ Advanced Settings
EI_00
EI_01

FIG. 41



Input Reference Container
Signal flow wire between input reference container and function block
Safety Monitoring
4202
SMF 1
EI_00
Reset
4204
+ Advanced Settings

FIG. 42

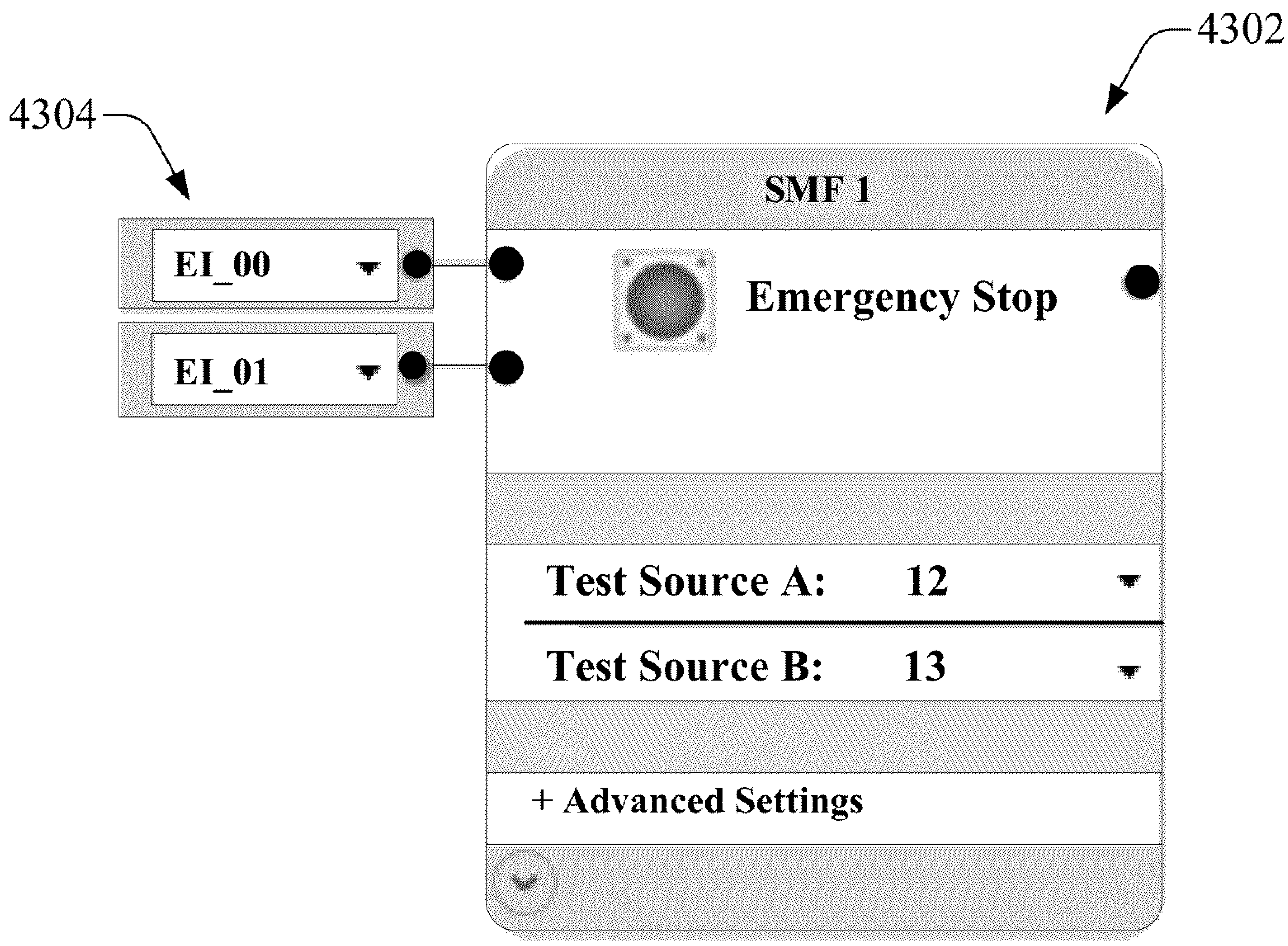

4302
4304
SMF 1
EI_00
EI_01
Emergency Stop
Test Source A: 12
Test Source B: 13
+ Advanced Settings

FIG. 43

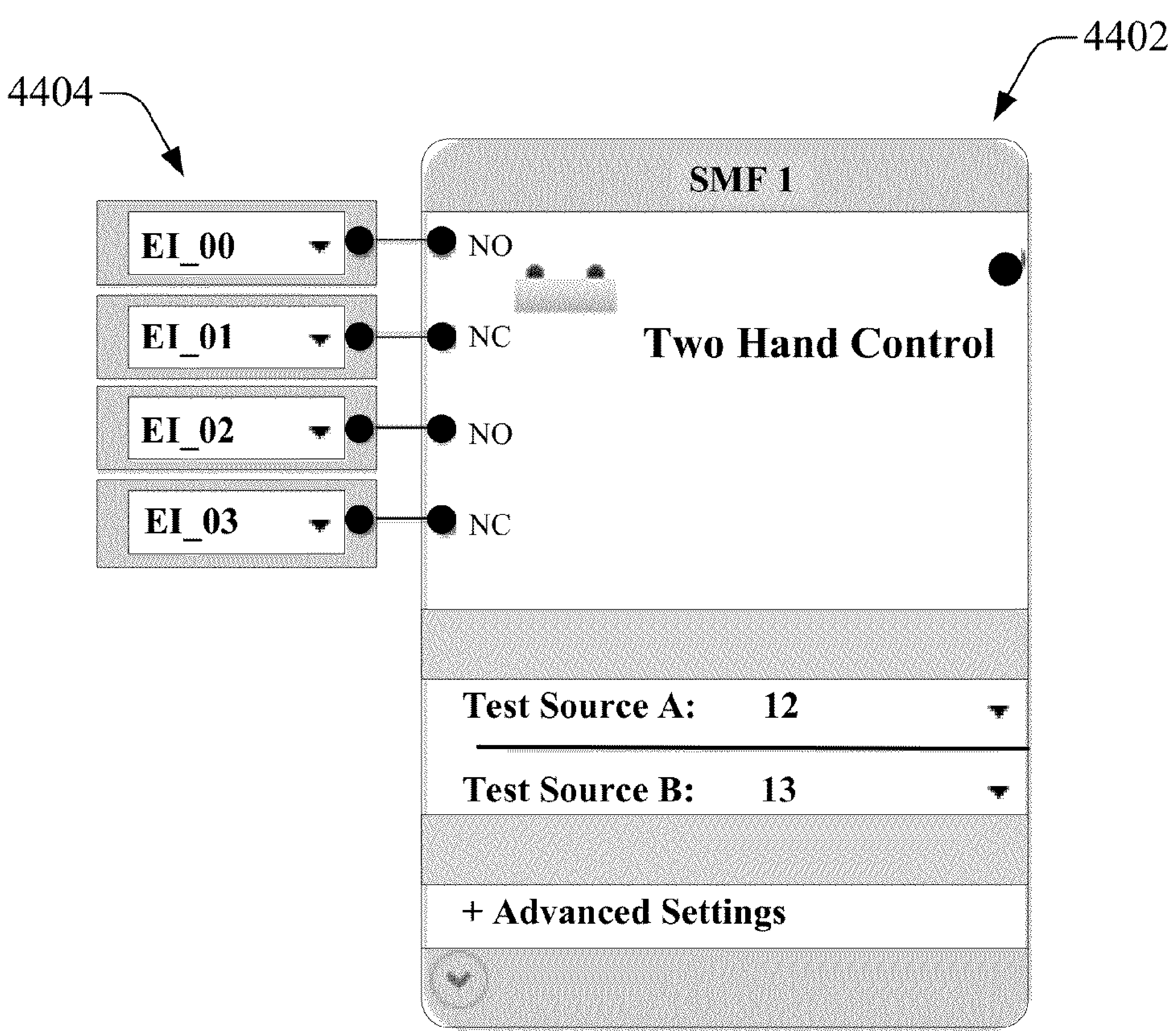

4402
4404
SMF 1
EI_00
EI_01
EI_02
EI_03
NO
NC
NO
NC
Two Hand Control
Test Source A: 12
Test Source B: 13
+ Advanced Settings

FIG. 44

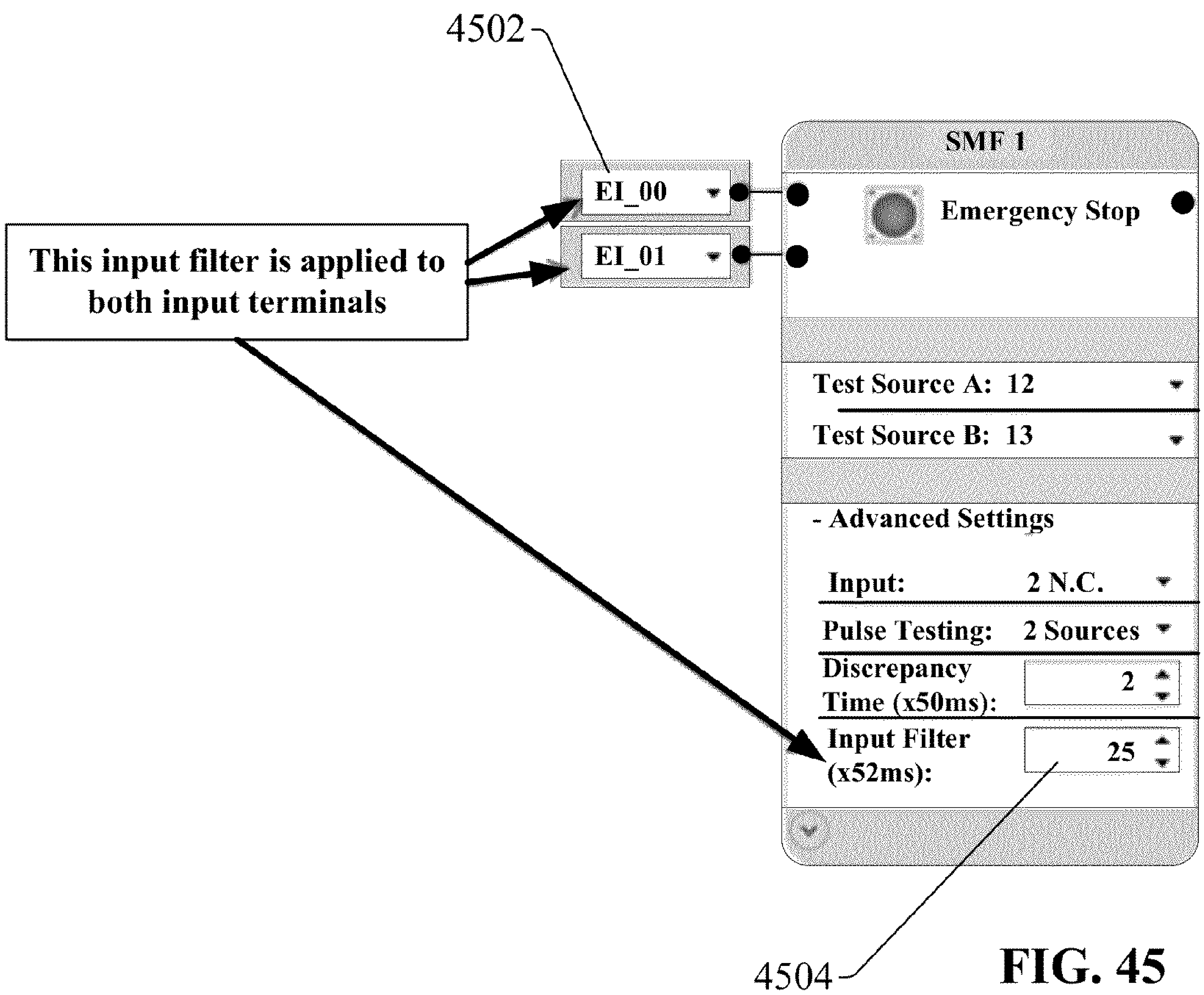

4502
This input filter is applied to both input terminals
EI_00
EI_01
SMF 1
Emergency Stop
Test Source A: 12
Test Source B: 13
- Advanced Settings
Input: 2 N.C.
Pulse Testing: 2 Sources
Discrepancy Time (x50ms): 2
Input Filter (x52ms): 25
4504

FIG. 45

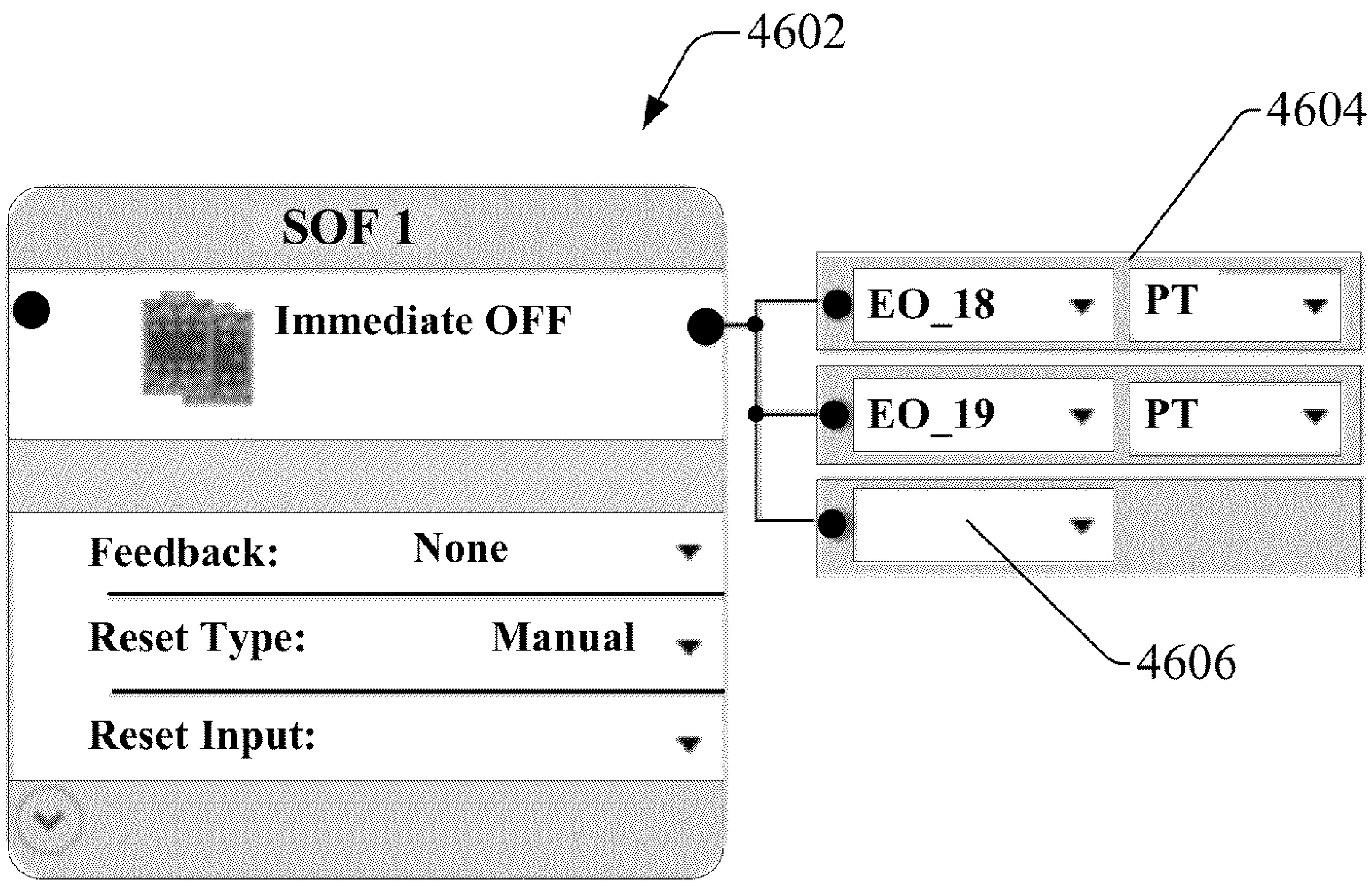


FIG. 46a

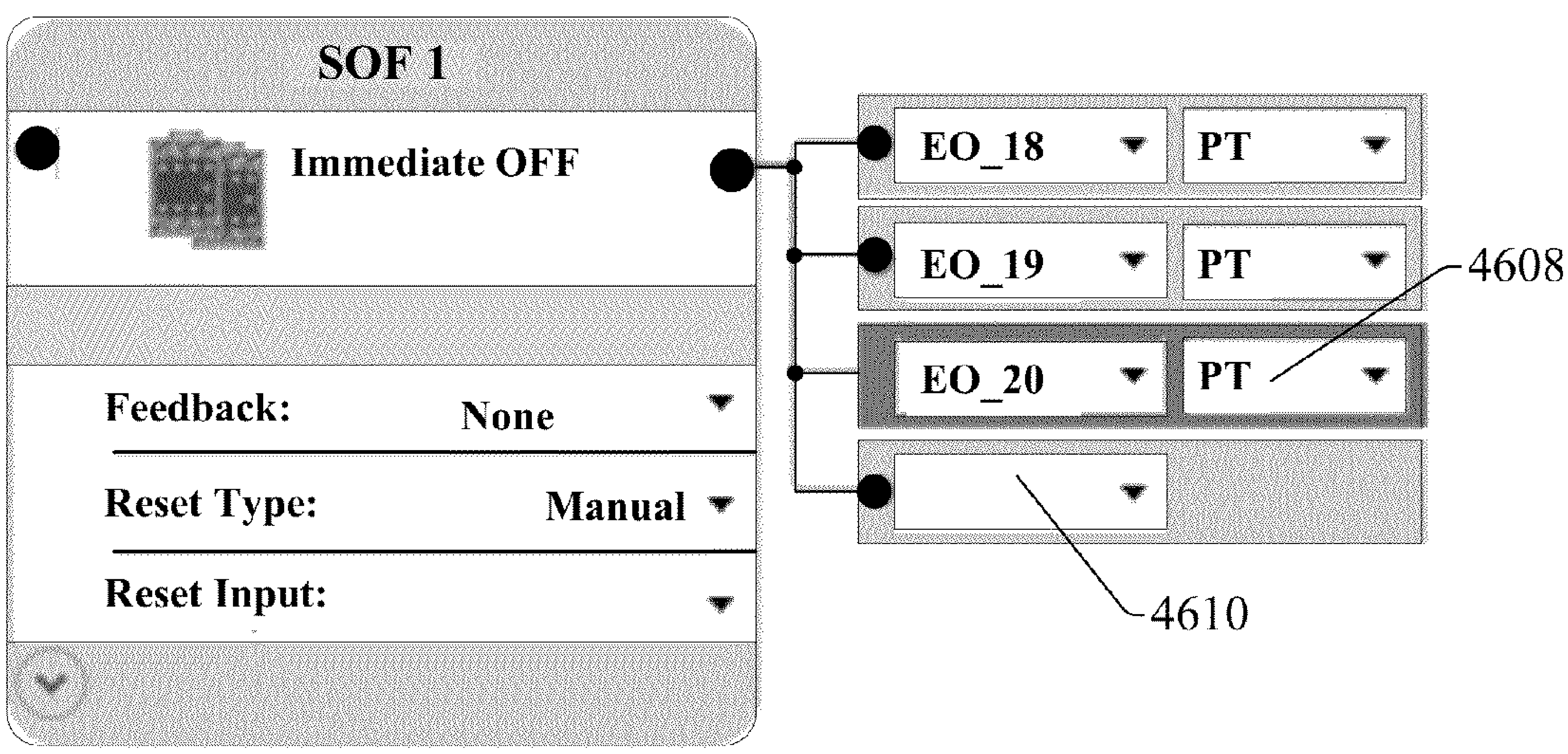


FIG. 46b

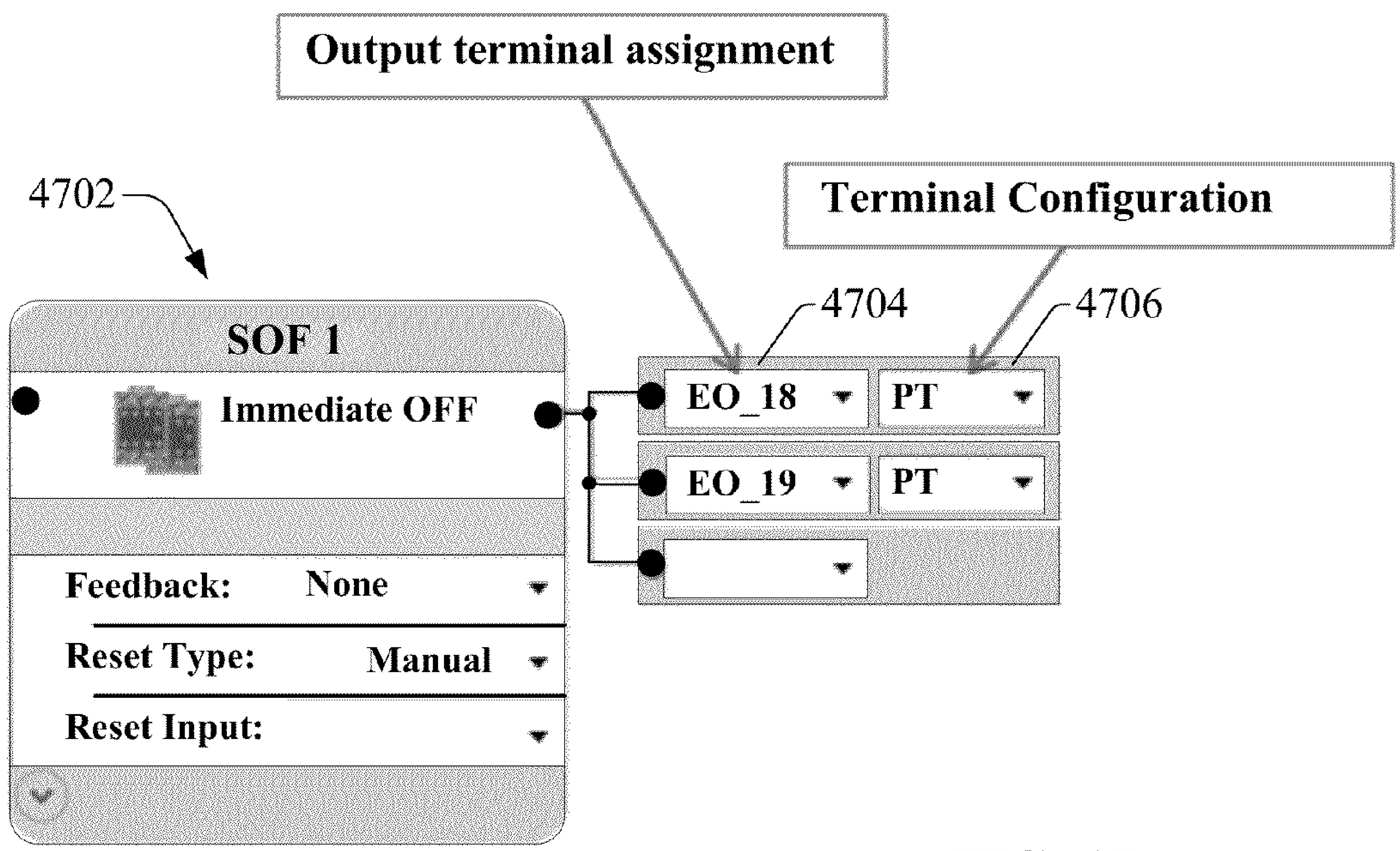

Output terminal assignment
Terminal Configuration
4702
4704
4706
SOF 1
Immediate OFF
EO_18
PT
EO_19
PT
Feedback: None
Reset Type: Manual
Reset Input:

FIG. 47

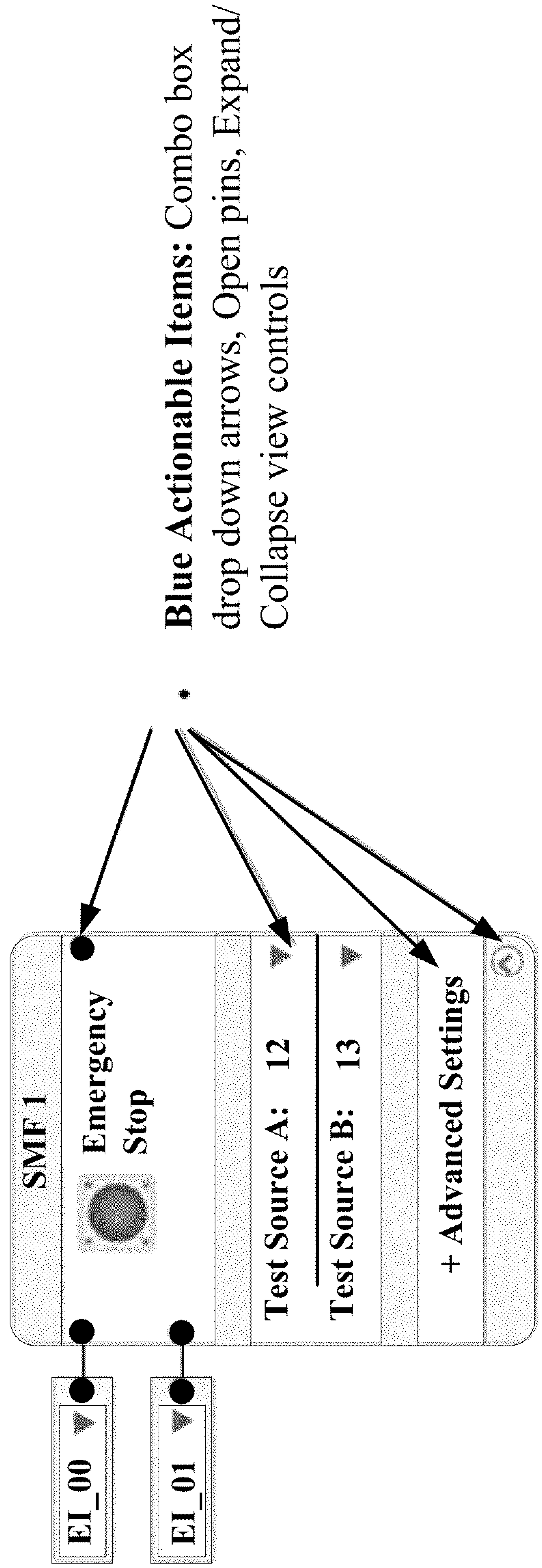

Blue Actionable Items: Combo box drop down arrows, Open pins, Expand/ Collapse view controls
SMF 1
Emergency Stop
Test Source A: 12
Test Source B: 13
+ Advanced Settings
EI_00
EI_01

FIG. 48

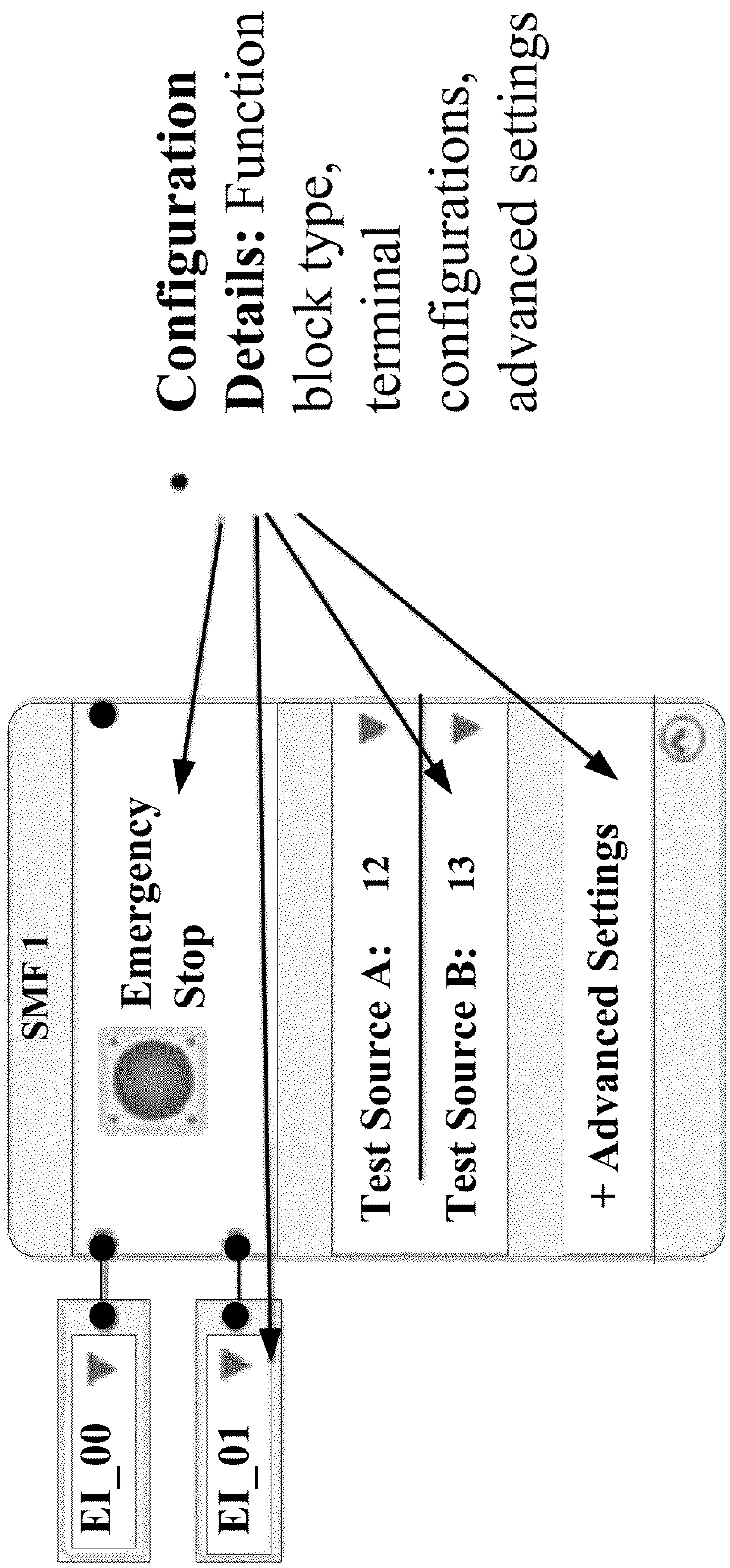

• Configuration Details: Function block type, terminal configurations, advanced settings
SMF 1
Emergency Stop
Test Source A: 12
Test Source B: 13
+ Advanced Settings
EI_00
EI_01

FIG. 49

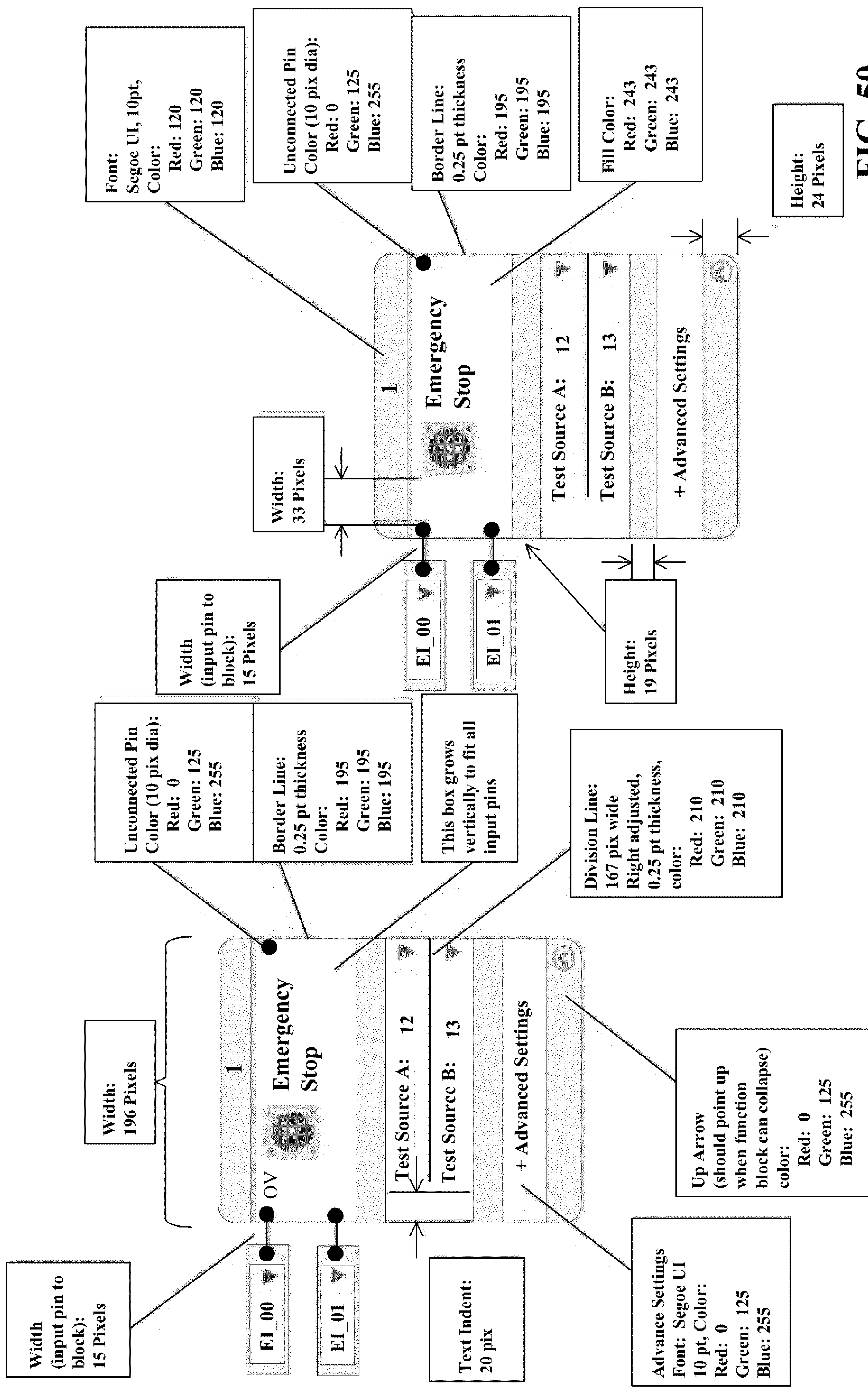

Font:
Segoe UI, 10pt,
Color:
Red: 120
Green: 120
Blue: 120
Unconnected Pin
Color (10 pix dia):
Red: 0
Green: 125
Blue: 255
Border Line:
0.25 pt thickness
Color:
Red: 195
Green: 195
Blue: 195
Fill Color:
Red: 243
Green: 243
Blue: 243
Height:
24 Pixels
Width:
33 Pixels
1
Emergency
Stop
Test Source A: 12
Test Source B: 13
+ Advanced Settings
Width
(input pin to
block):
15 Pixels
EI_00
EI_01
Height:
19 Pixels
Unconnected Pin
Color (10 pix dia):
Red: 0
Green: 125
Blue: 255
Border Line:
0.25 pt thickness
Color:
Red: 195
Green: 195
Blue: 195
This box grows
vertically to fit all
input pins
Division Line:
167 pix wide
Right adjusted,
0.25 pt thickness,
color:
Red: 210
Green: 210
Blue: 210
Width:
196 Pixels
OV
1
Emergency
Stop
Test Source A: 12
Test Source B: 13
+ Advanced Settings
Up Arrow
(should point up
when function
block can collapse)
color:
Red: 0
Green: 125
Blue: 255
Width
(input pin to
block):
15 Pixels
EI_00
EI_01
Text Indent:
20 pix
Advance Settings
Font: Segoe UI
10 pt, Color:
Red: 0
Green: 125
Blue: 255

FIG. 50

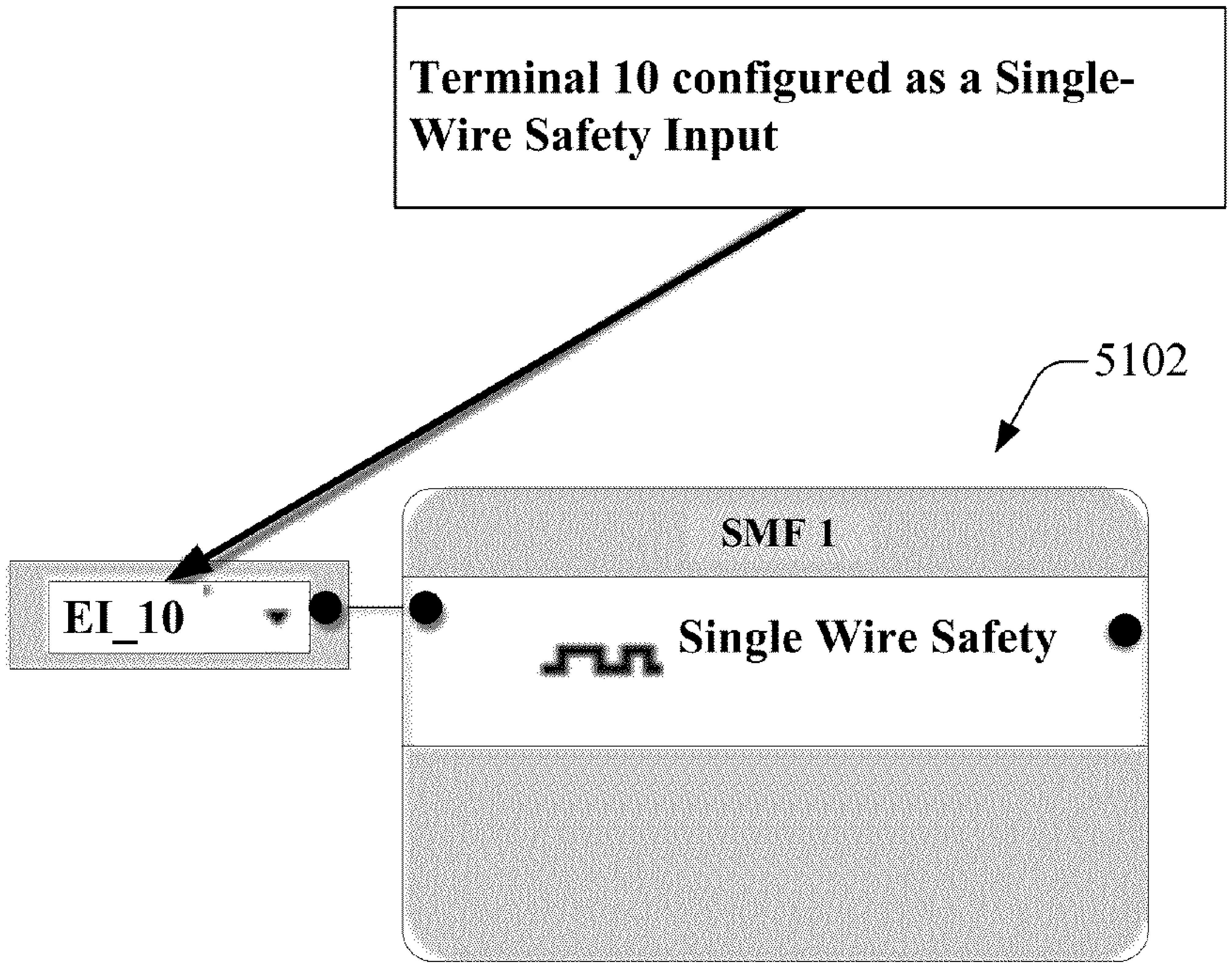


FIG. 51a

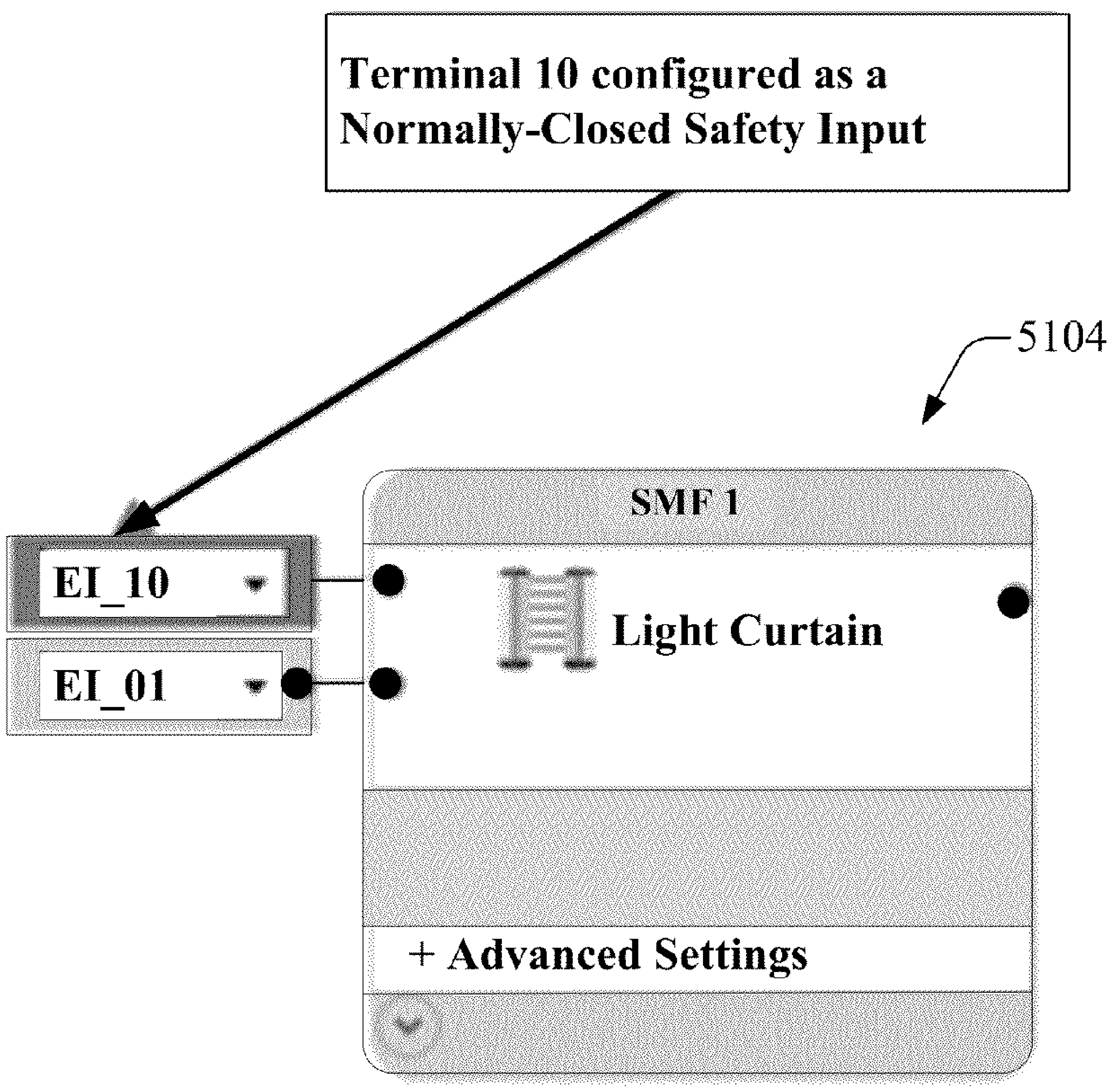


FIG. 51b

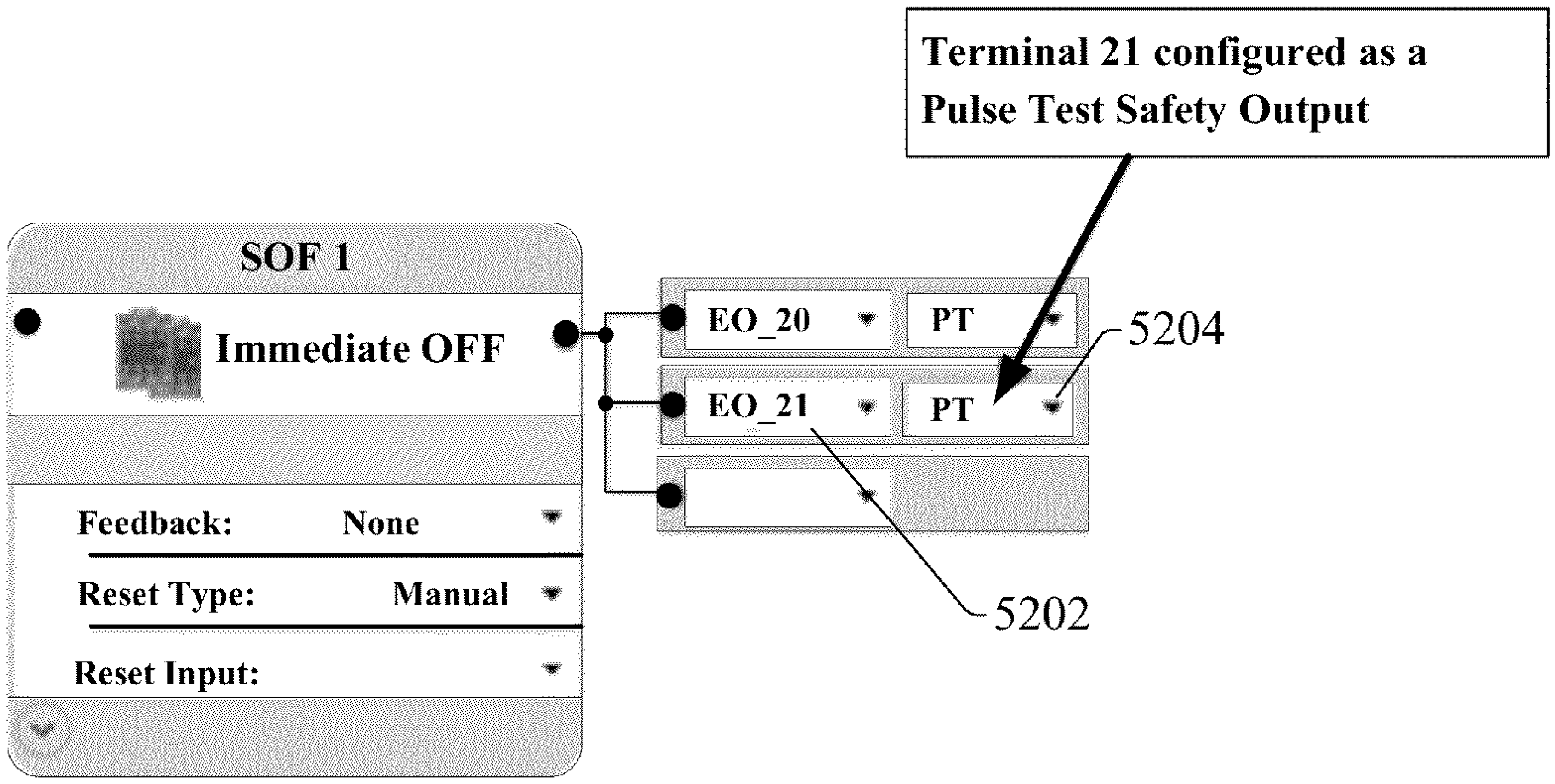


FIG. 52a

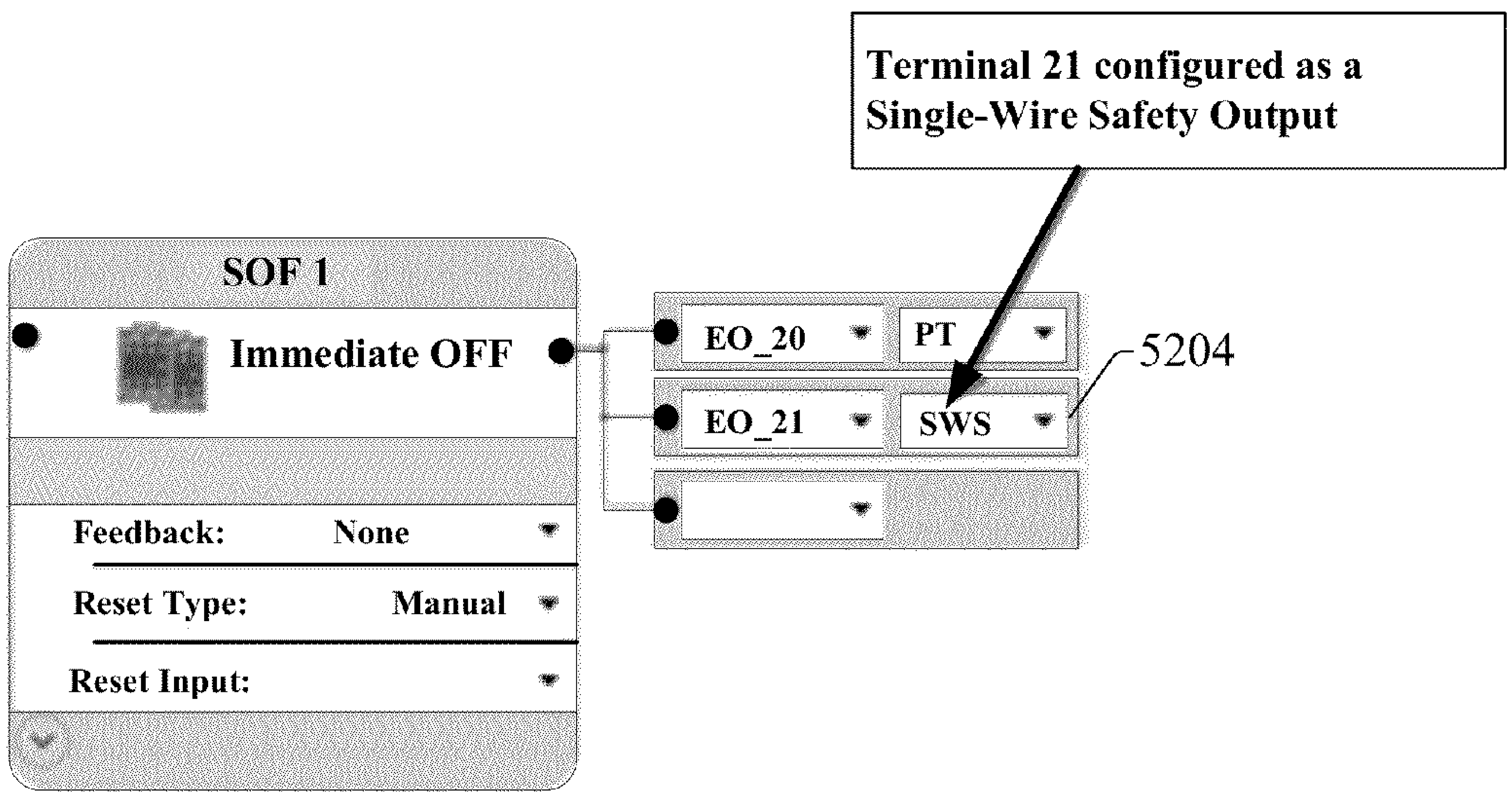


FIG. 52b

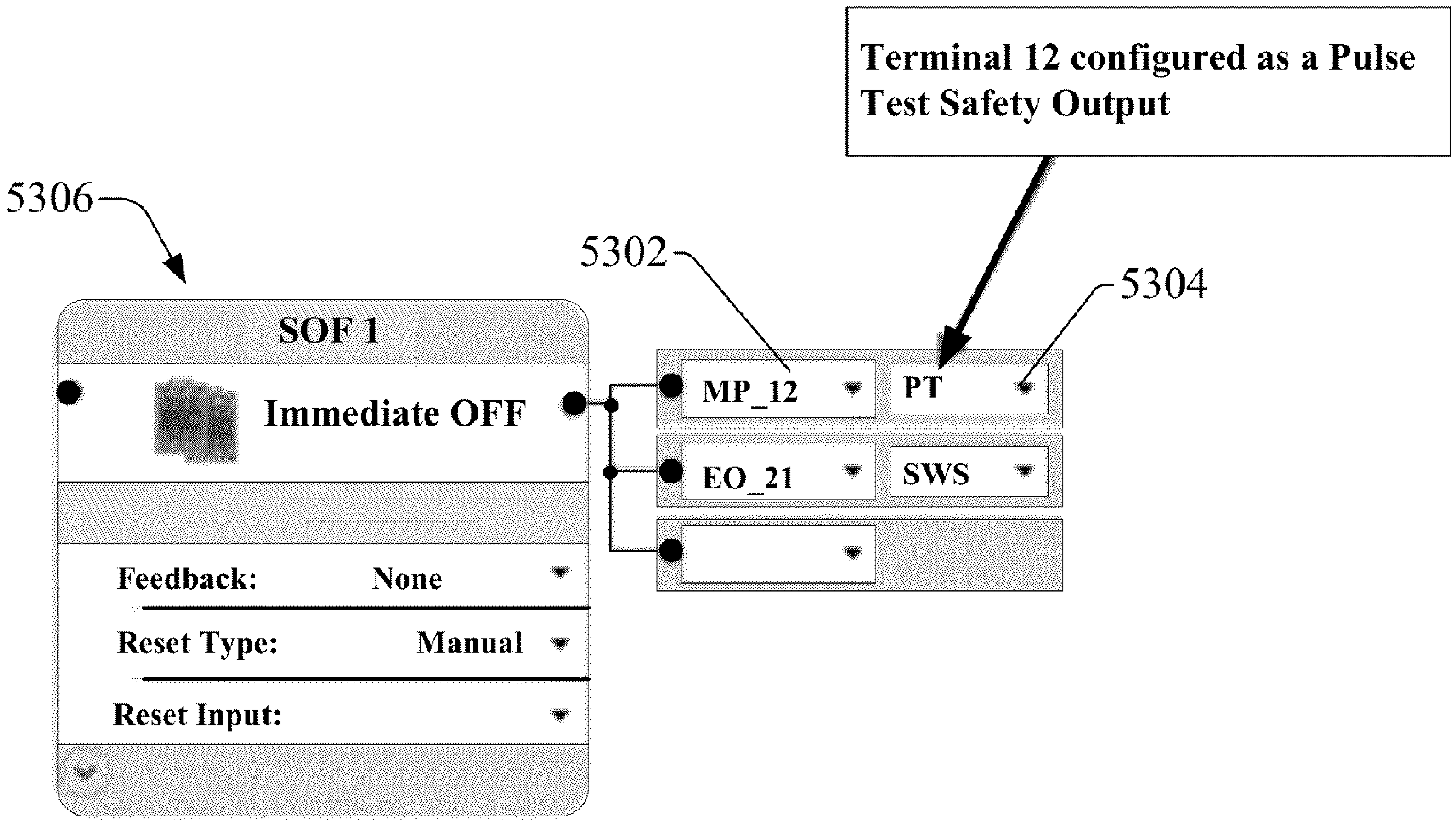


FIG. 53a

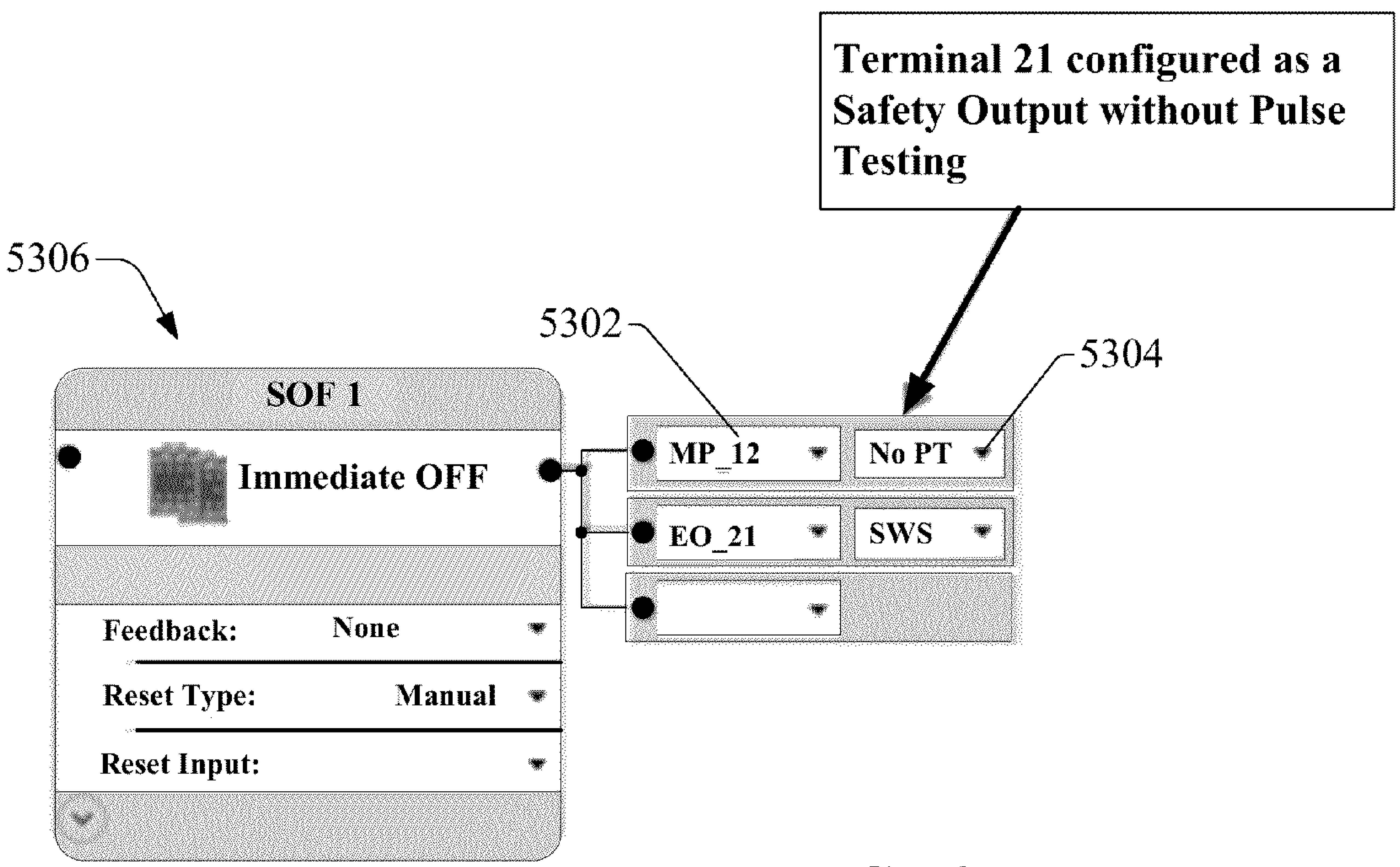


FIG. 53b

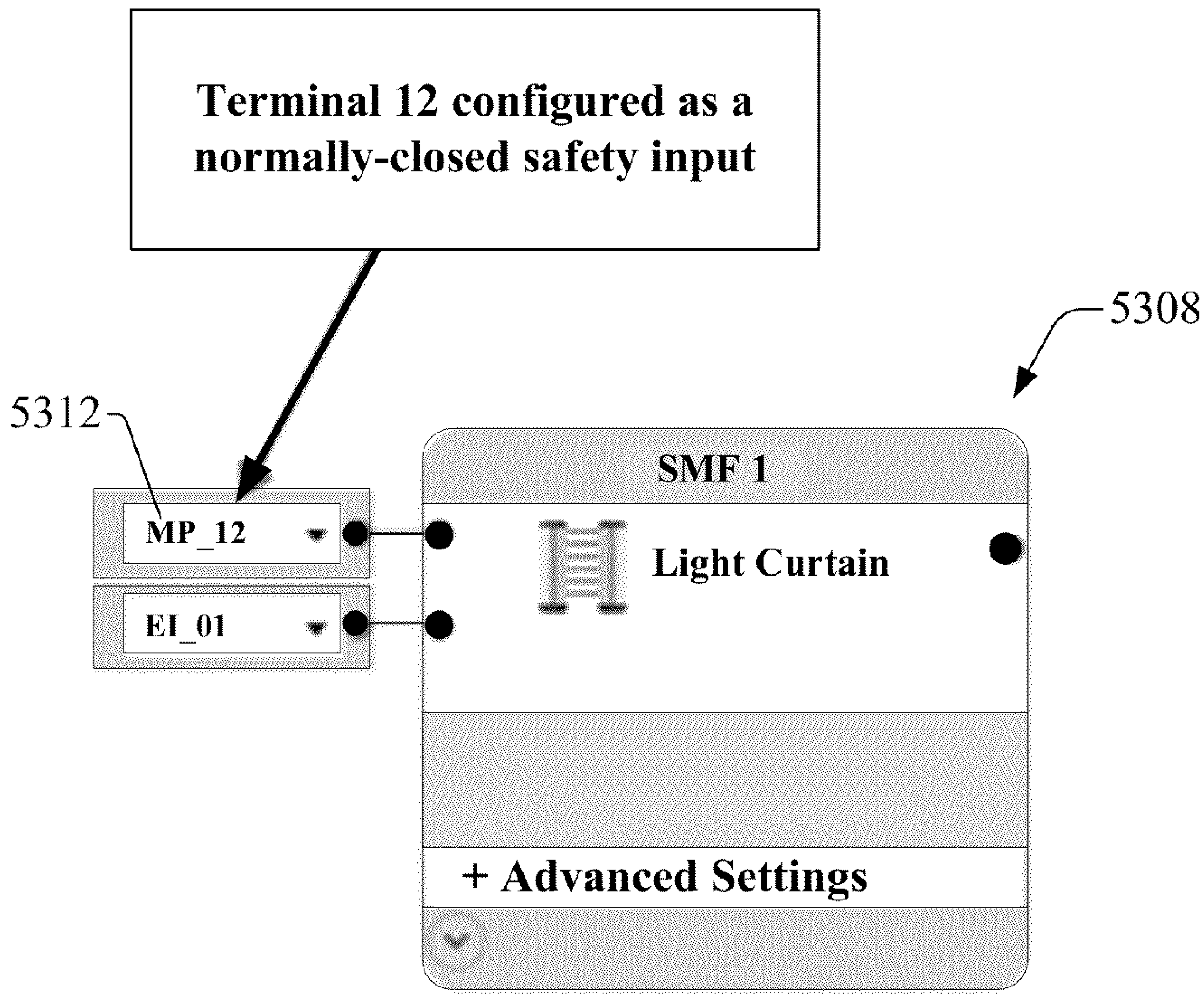


FIG. 53c

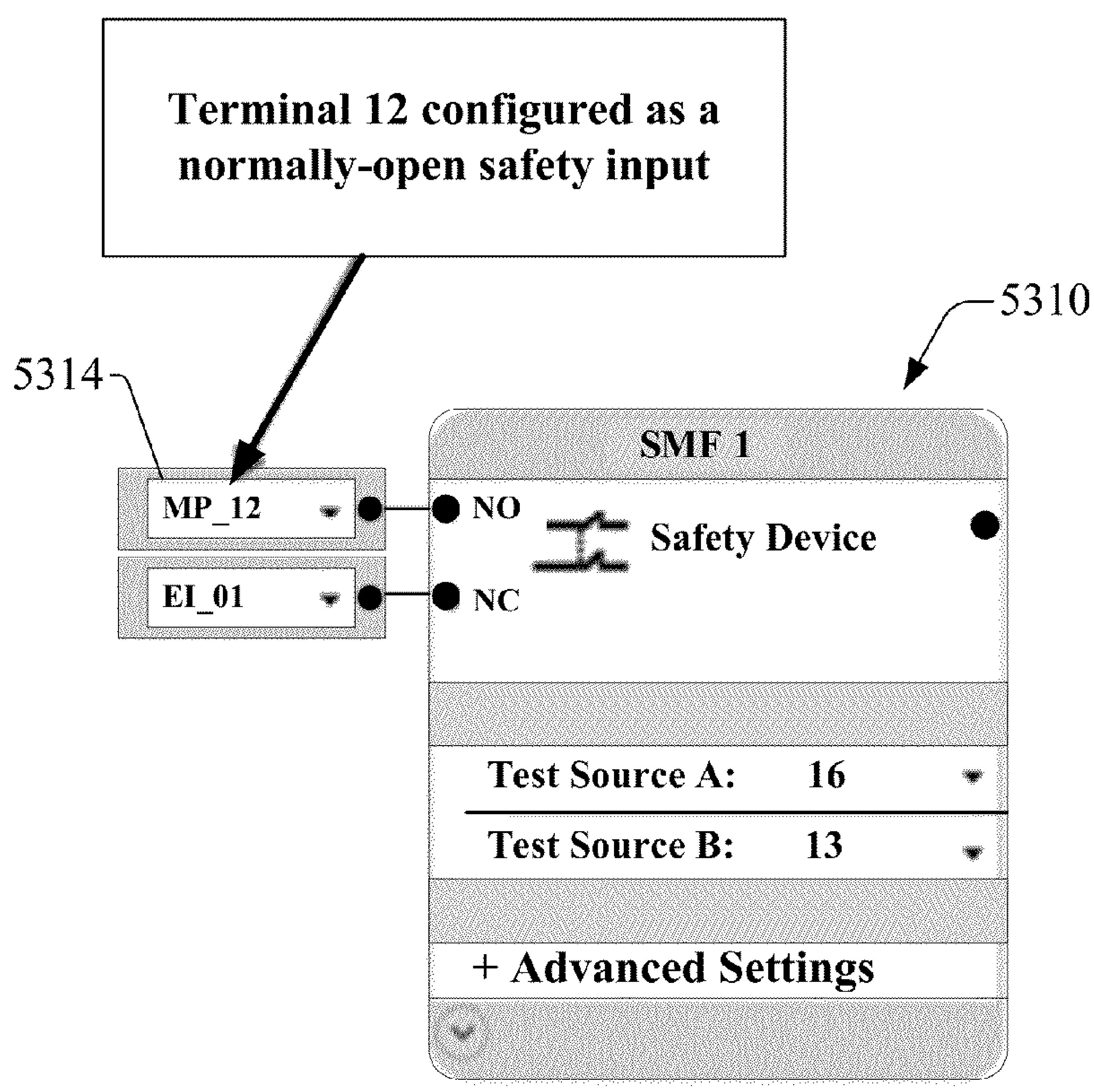


FIG. 53d

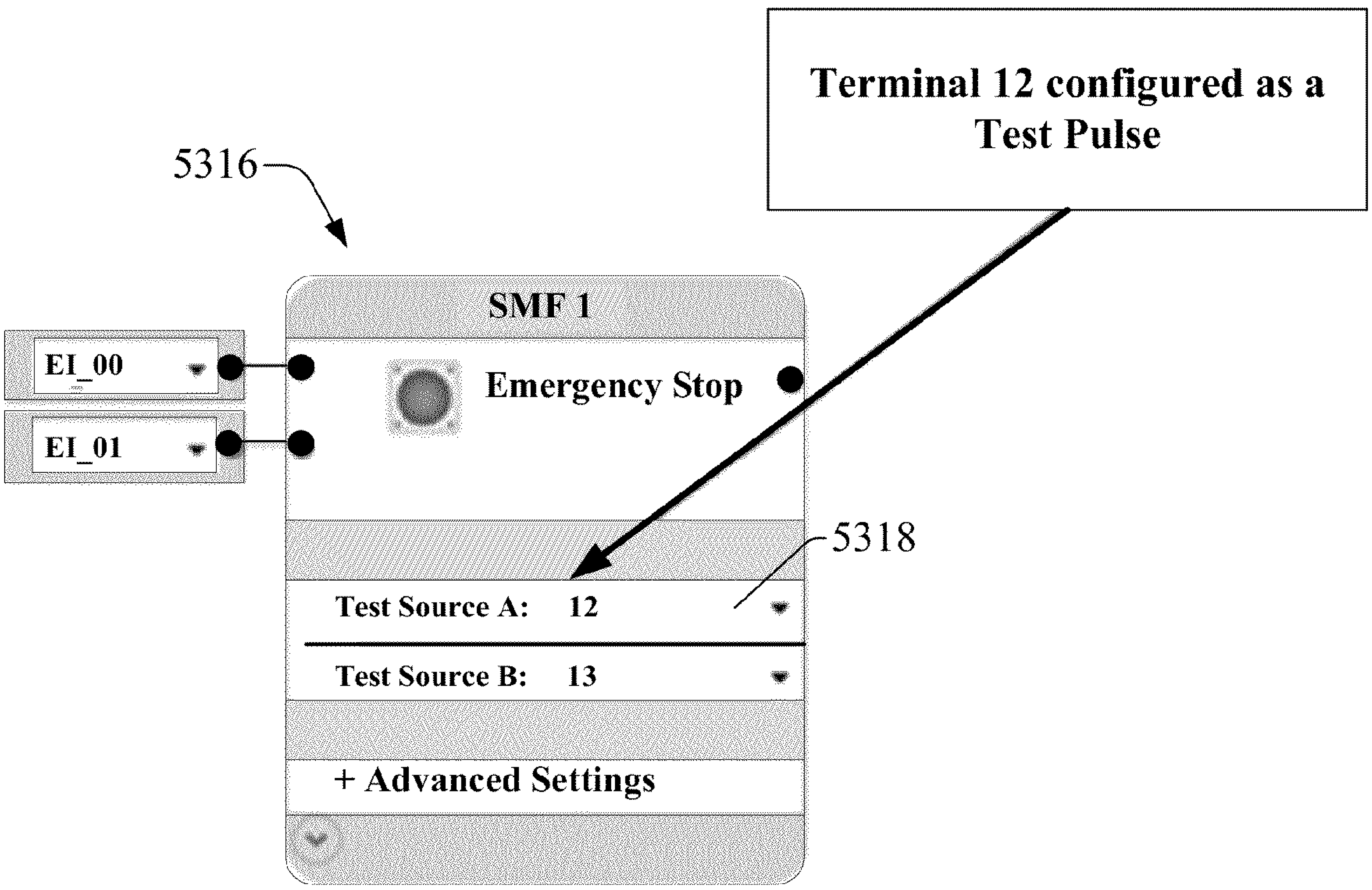

Terminal 12 configured as a Test Pulse
5316
SMF 1
EI_00
EI_01
Emergency Stop
5318
Test Source A: 12
Test Source B: 13
+ Advanced Settings

FIG. 53e

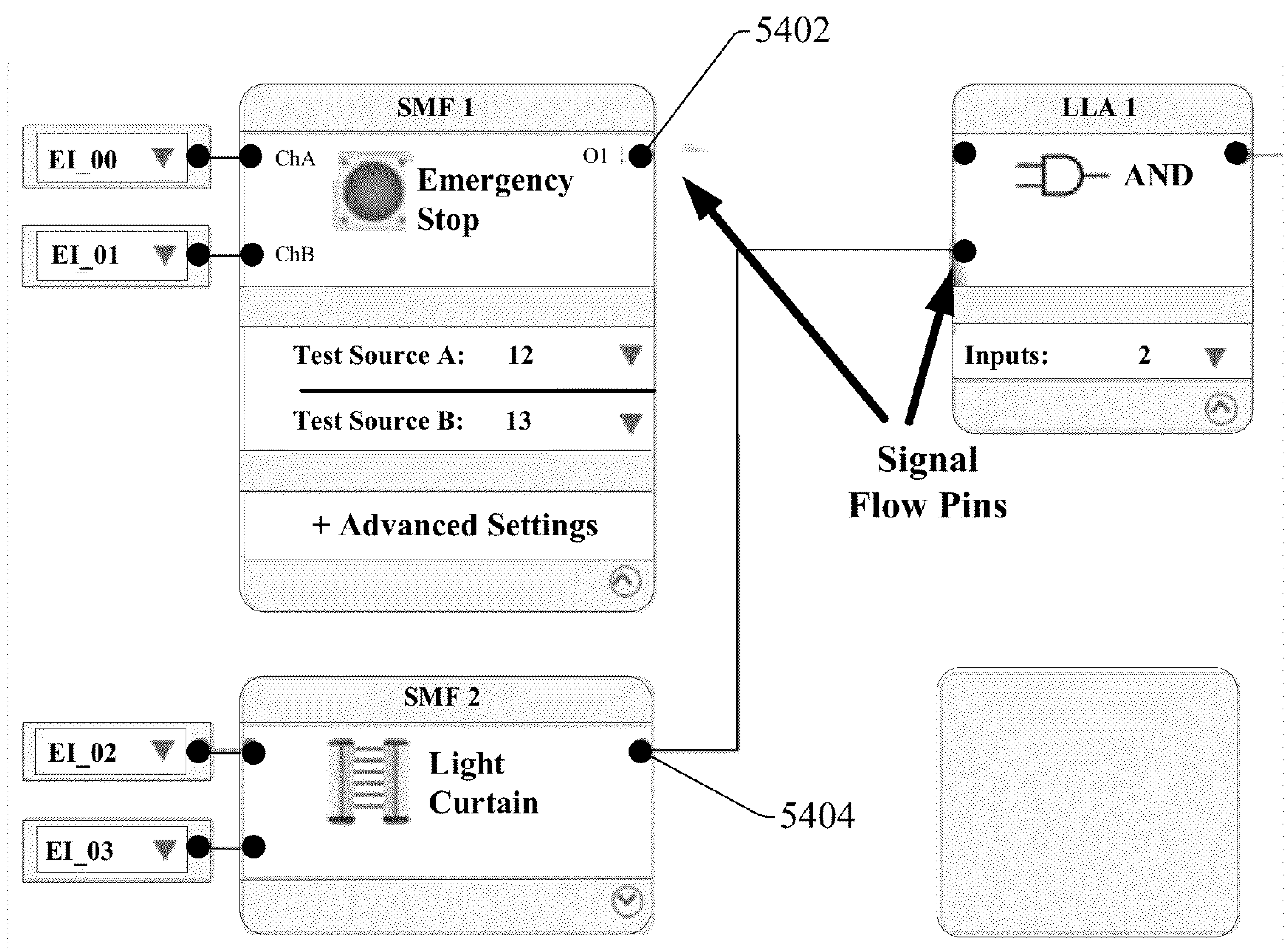

5402
SMF 1
EI_00
EI_01
ChA
ChB
Emergency
Stop
O1
Test Source A: 12
Test Source B: 13
+ Advanced Settings
LLA 1
AND
Inputs: 2
Signal
Flow Pins
SMF 2
EI_02
EI_03
Light
Curtain
5404

FIG. 54

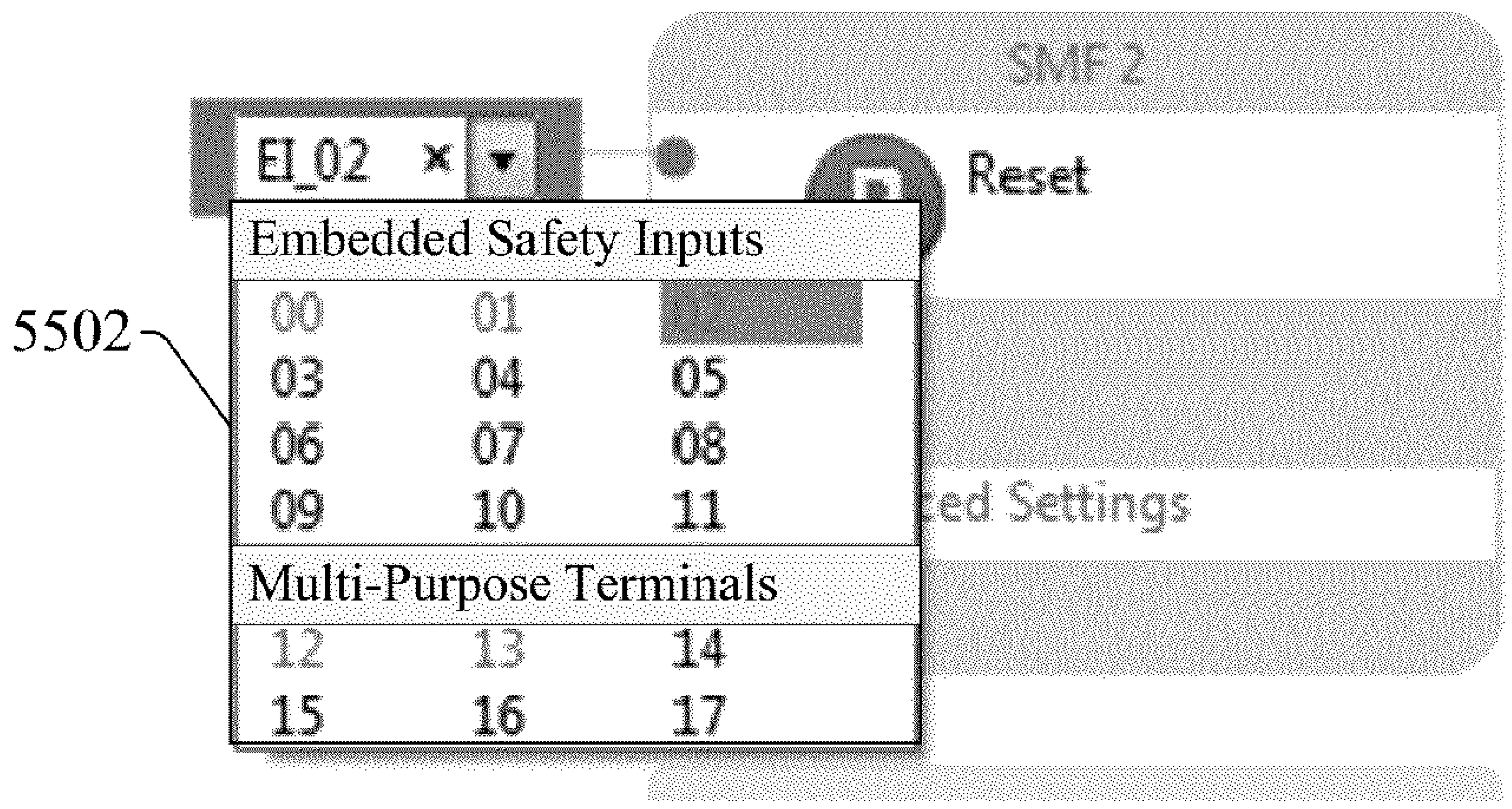


FIG. 55a

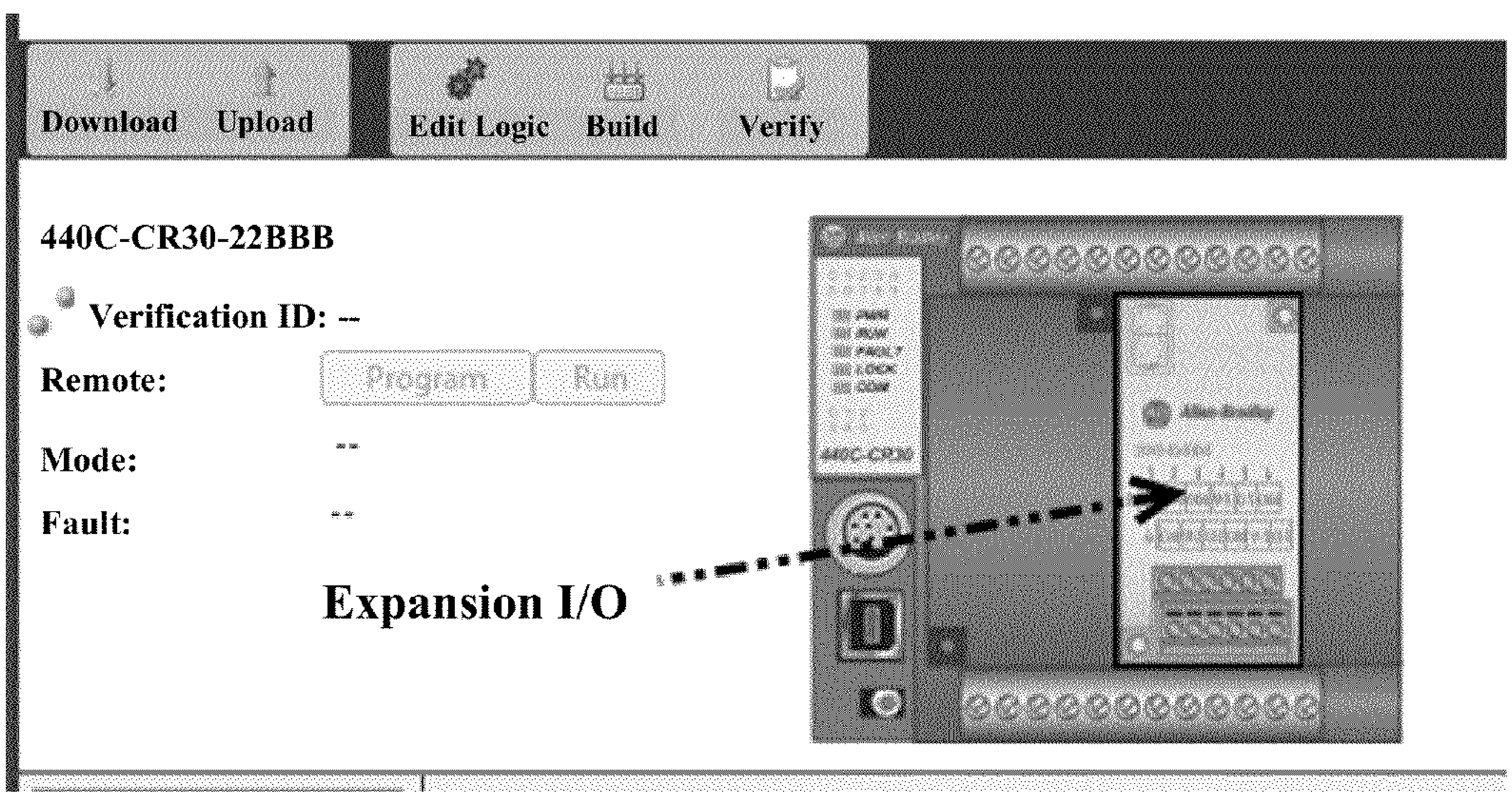


FIG. 55b

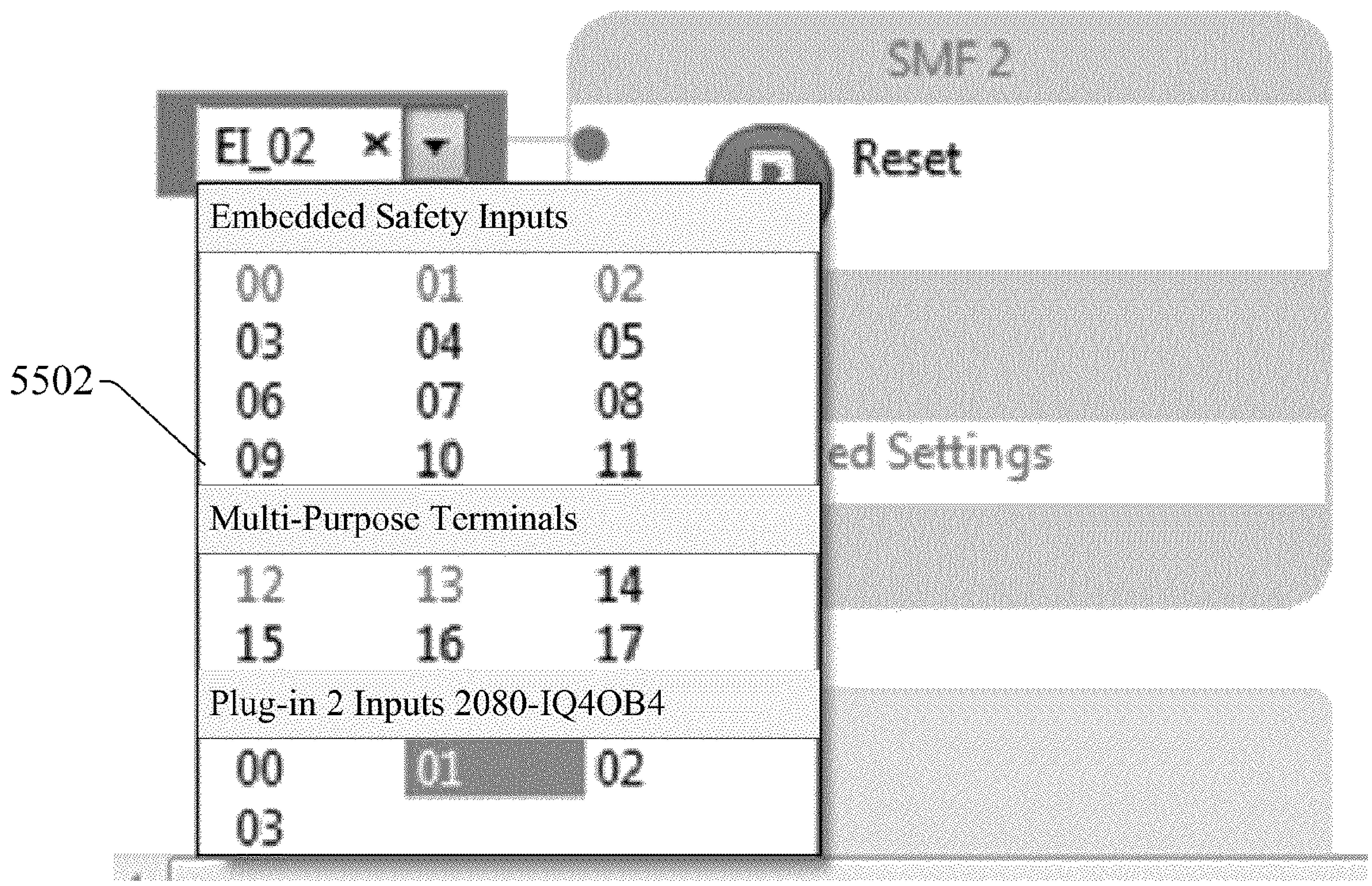

SMF 2
EI_02
Reset
Embedded Safety Inputs
00 01 02
03 04 05
06 07 08
09 10 11
5502
ed Settings
Multi-Purpose Terminals
12 13 14
15 16 17
Plug-in 2 Inputs 2080-IQ4OB4
00 01 02
03

FIG. 55c

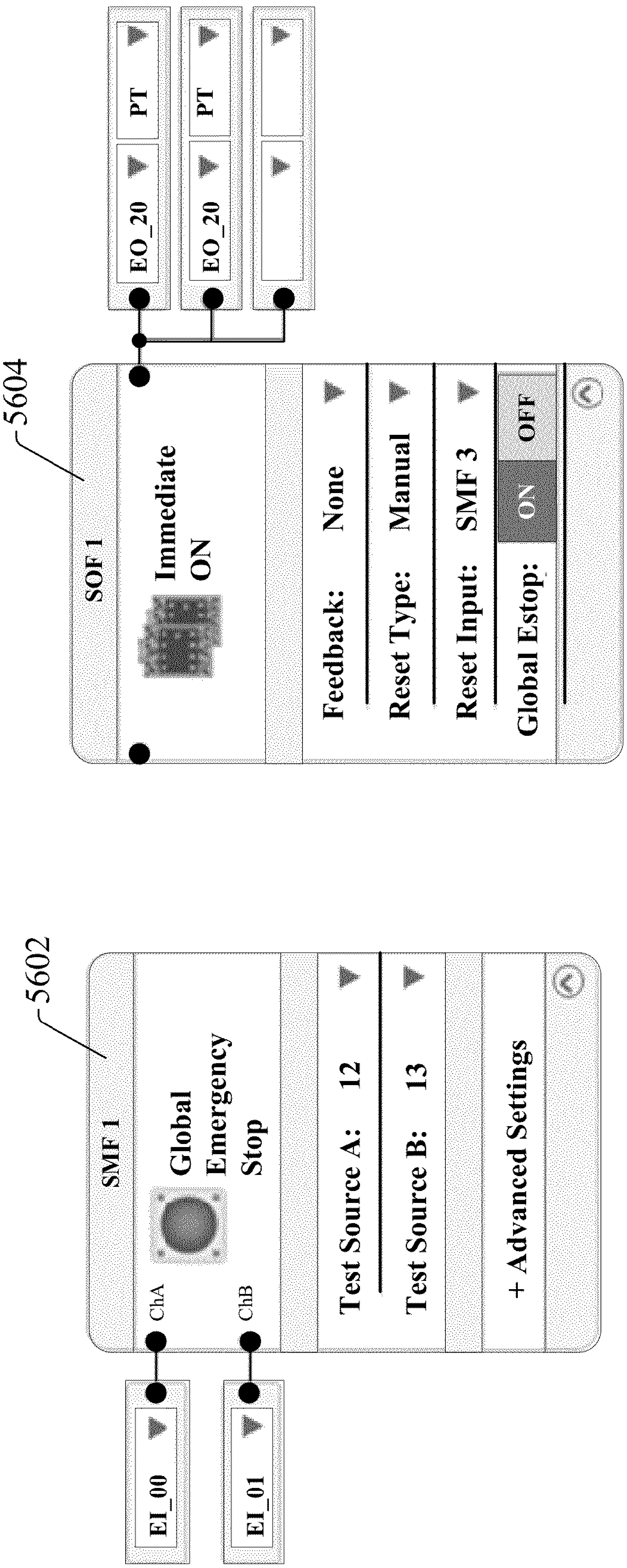

5604
SOF 1
Immediate
ON
Feedback: None
Reset Type: Manual
Reset Input: SMF 3
Global Estop:
ON
OFF
EO_20
PT
EO_20
PT
5602
SMF 1
Global
Emergency
Stop
ChA
ChB
Test Source A: 12
Test Source B: 13
+ Advanced Settings
EI_00
EI_01

FIG. 56

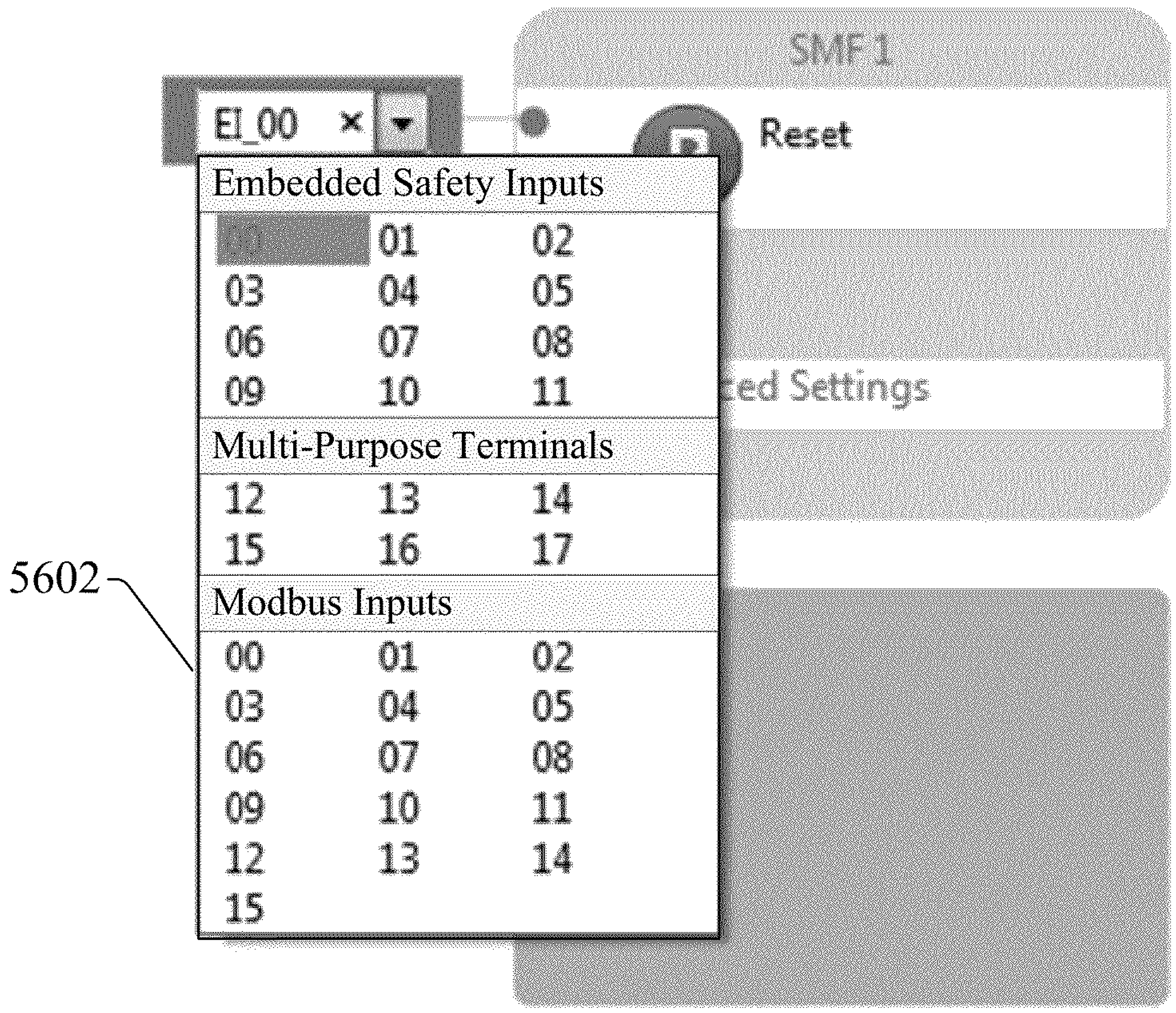

SMF 1
EI_00
Reset
Embedded Safety Inputs
00 01 02
03 04 05
06 07 08
09 10 11
ced Settings
Multi-Purpose Terminals
12 13 14
15 16 17
5602
Modbus Inputs
00 01 02
03 04 05
06 07 08
09 10 11
12 13 14
15

FIG. 57


Safety Relay
Serial Port
USB Port
LED Configuration
Faults
Modbus Mapping
Plug-In Modules
Empty
Empty
Safety Relay - Modbus Mapping
Address
Addresses Used
Parameter
000025
000025-000040
Input/Output Data for Plug In 1
000265
000265-000272
Overall Status
000273
000273-000296
Input/Output data for embedded terminals
000297
000297-000304
Input/Output data for Plug In 2
000305
000305-000328
State of SMF
000329
000329-000344
State of LLA
000345
000345-000360
State of LLB
000361
000361-000376
State of SOF
000377
000377-000392
Ready-to-start of SOF
000393
000393-000416
Fault bit 0 of SMFs

FIG. 58

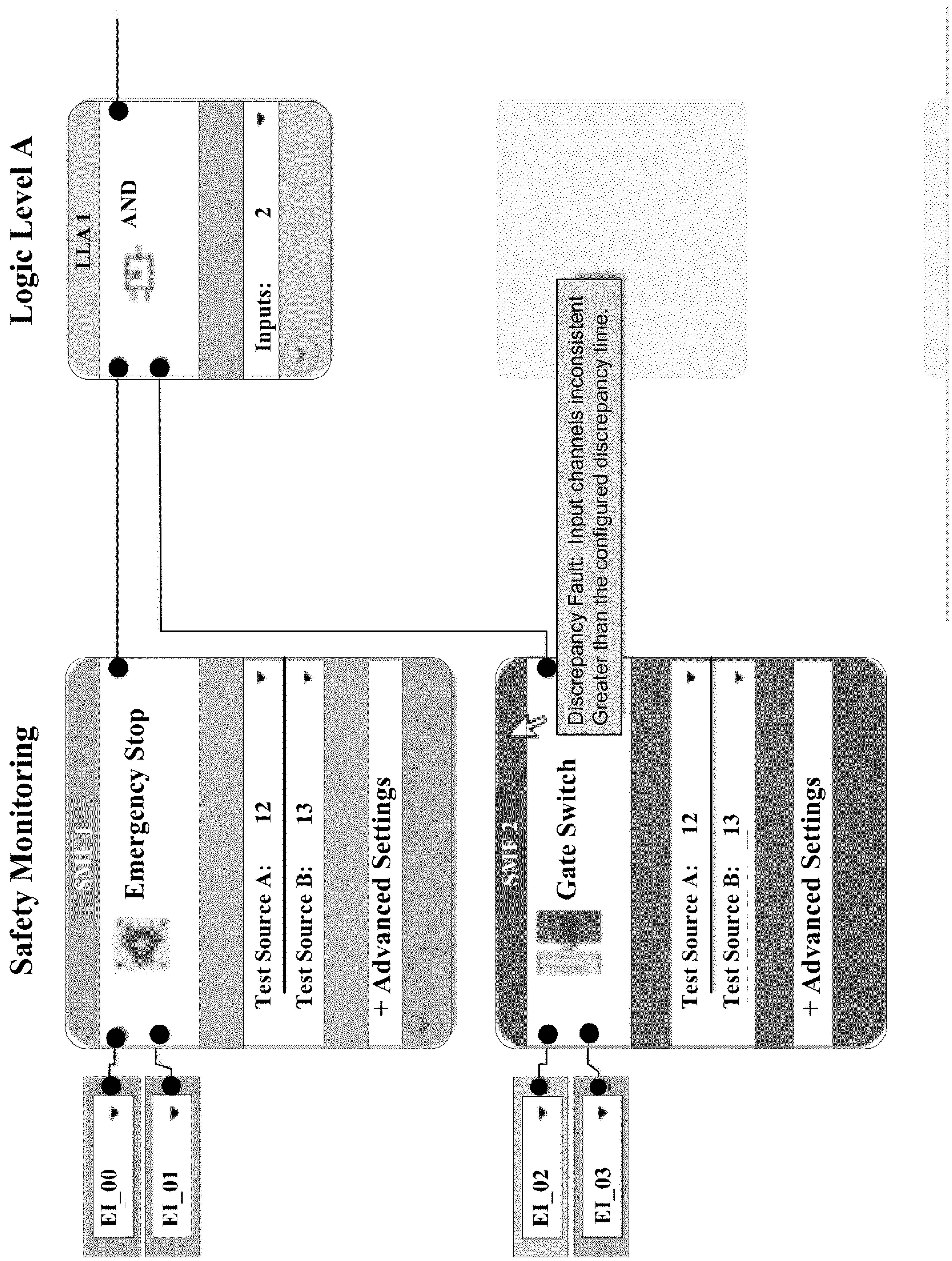

Safety Monitoring
SMF 1
Emergency Stop
Test Source A: 12
Test Source B: 13
+ Advanced Settings
EI_00
EI_01
SMF 2
Gate Switch
Test Source A: 12
Test Source B: 13
+ Advanced Settings
EI_02
EI_03
Logic Level A
LLA 1
AND
Inputs: 2
Discrepancy Fault: Input channels inconsistent
Greater than the configured discrepancy time.

FIG. 59

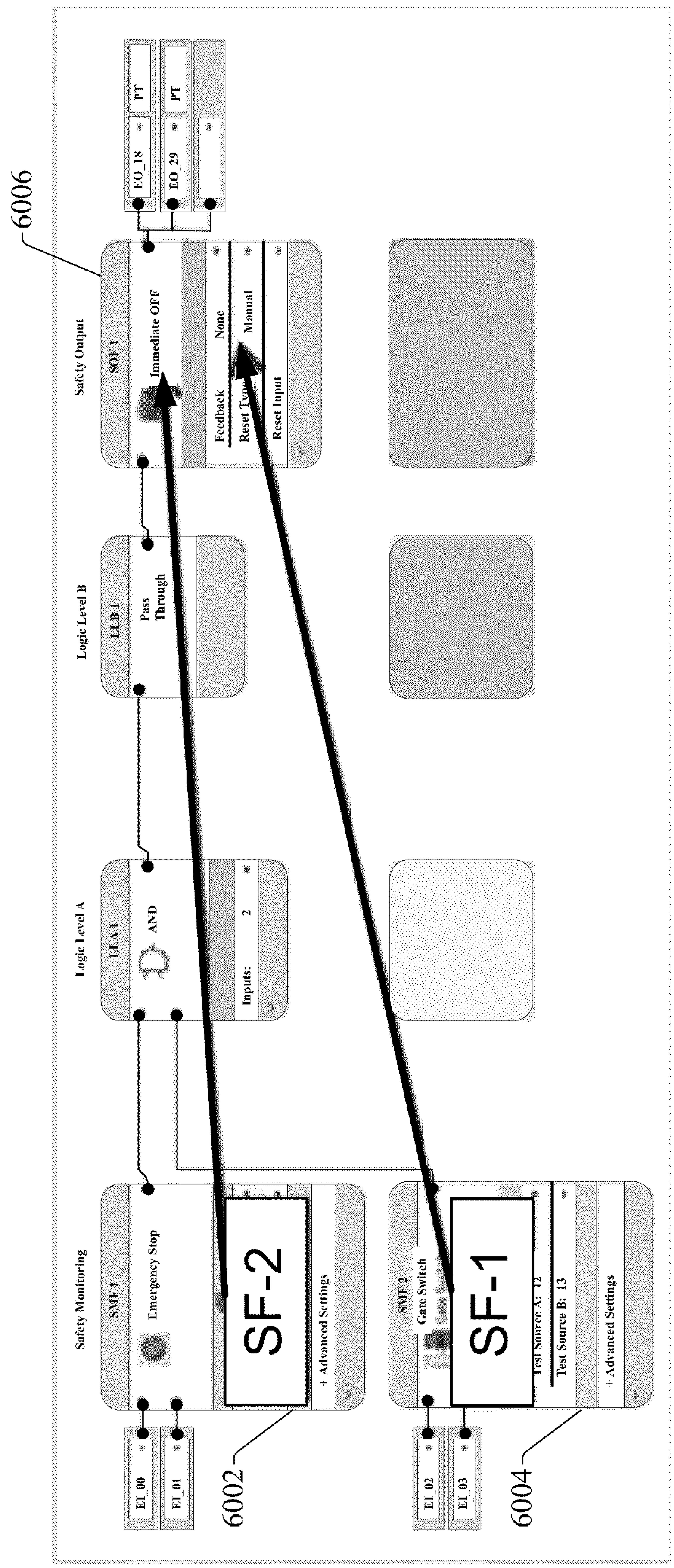
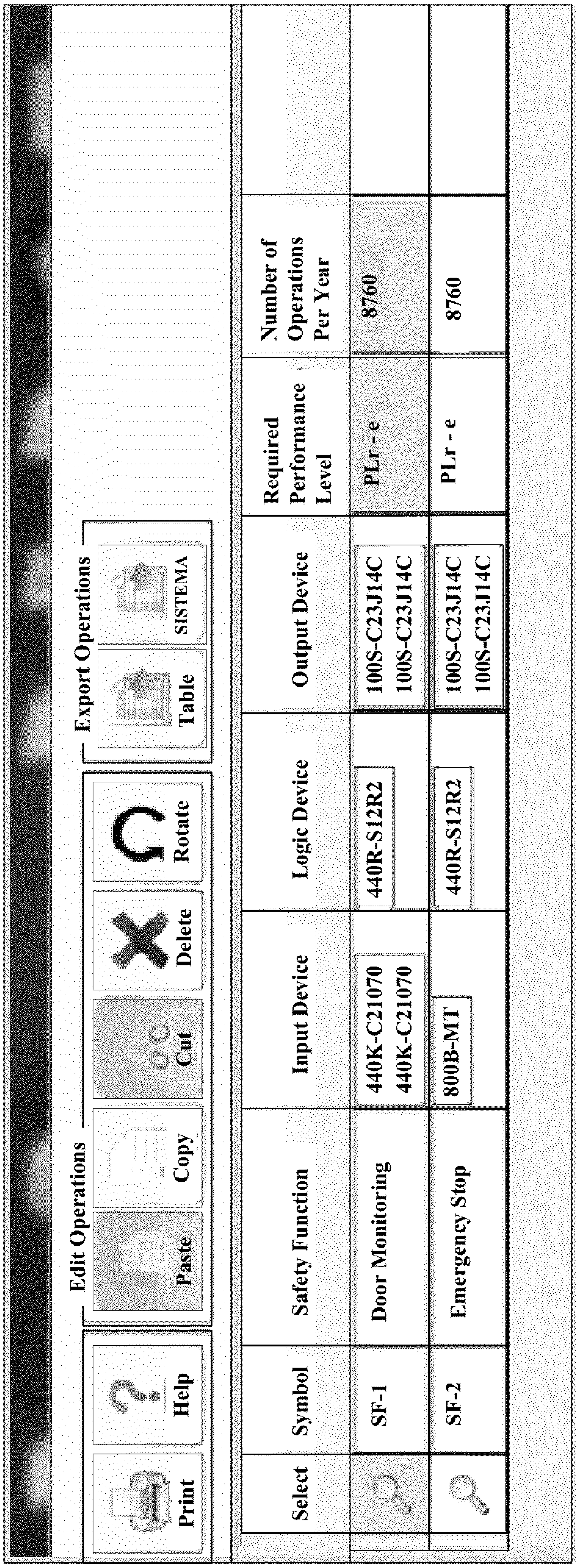

Safety Monitoring
SMF 1
Emergency Stop
SF-2
+ Advanced Settings
EI_00
EI_01
6002
SMF 2
Gate Switch
SF-1
Test Source A: 12
Test Source B: 13
+ Advanced Settings
EI_02
EI_03
6004
Logic Level A
LLA 1
AND
Inputs: 2
Logic Level B
LLB 1
Pass Through
Safety Output
SOF 1
Immediate OFF
Feedback None
Reset Type Manual
Reset Input
EO_18
EO_29
PT
PT
6006

FIG. 60



Print
Help
Edit Operations
Paste
Copy
Cut
Delete
Rotate
Export Operations
Table
SISTEMA
Select
Symbol
Safety Function
Input Device
Logic Device
Output Device
Required Performance Level
Number of Operations Per Year
SF-1
Door Monitoring
440K-C21070
440K-C21070
440R-S12R2
100S-C23J14C
100S-C23J14C
PLr - e
8760
SF-2
Emergency Stop
800B-MT
440R-S12R2
100S-C23J14C
100S-C23J14C
PLr - e
8760

FIG. 61

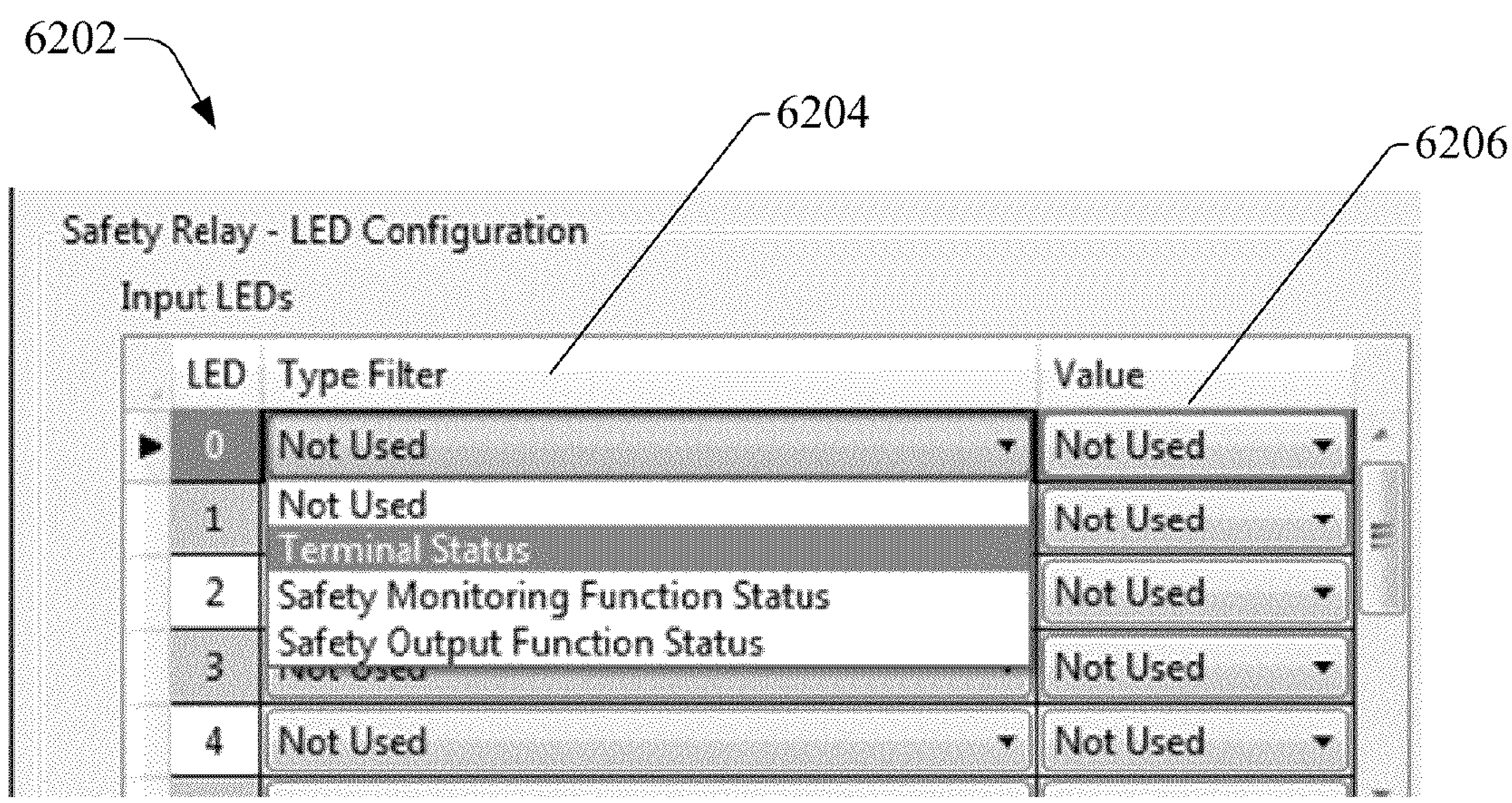


FIG. 62a

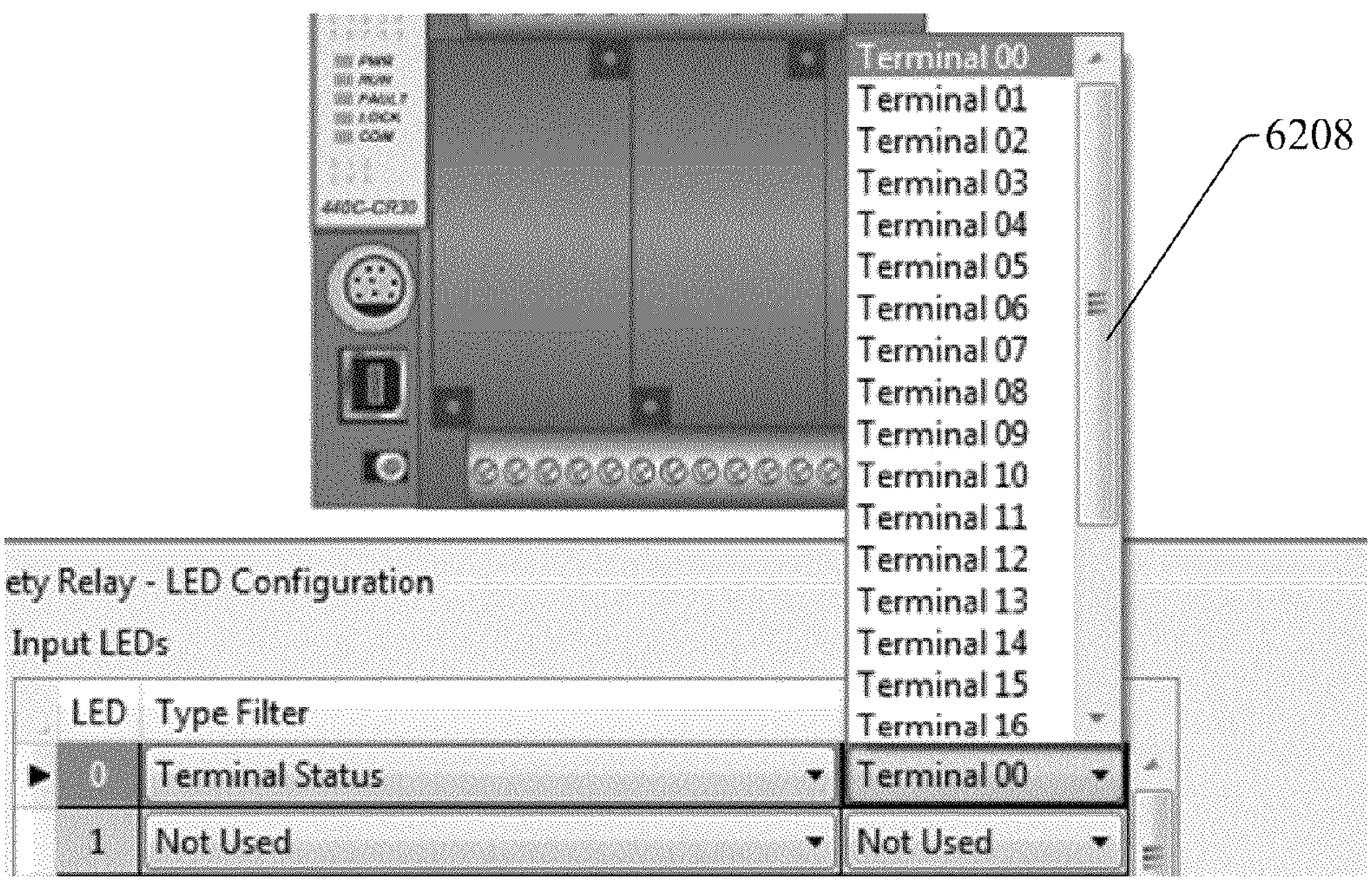


FIG. 62b

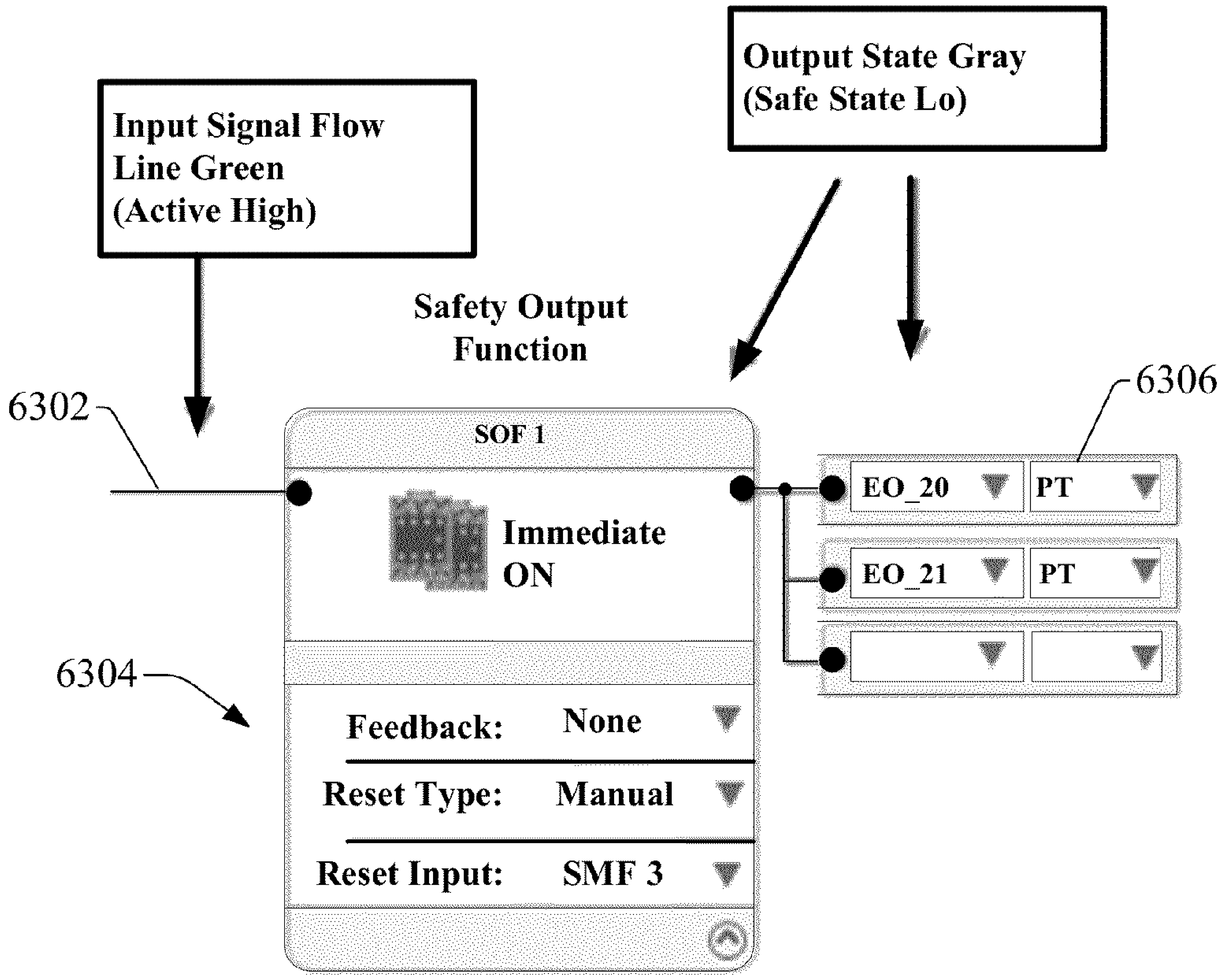


FIG. 63a

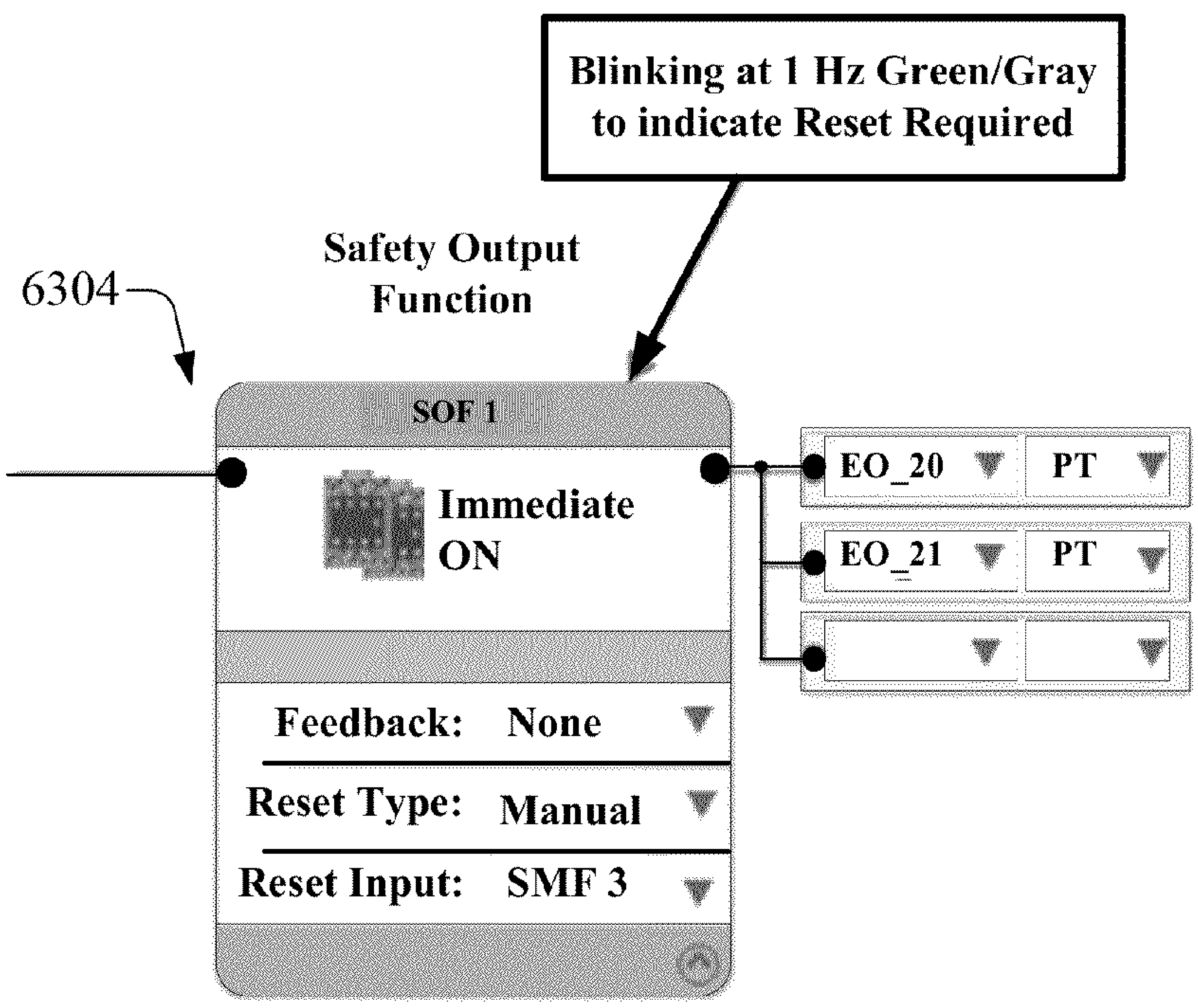


FIG. 63b

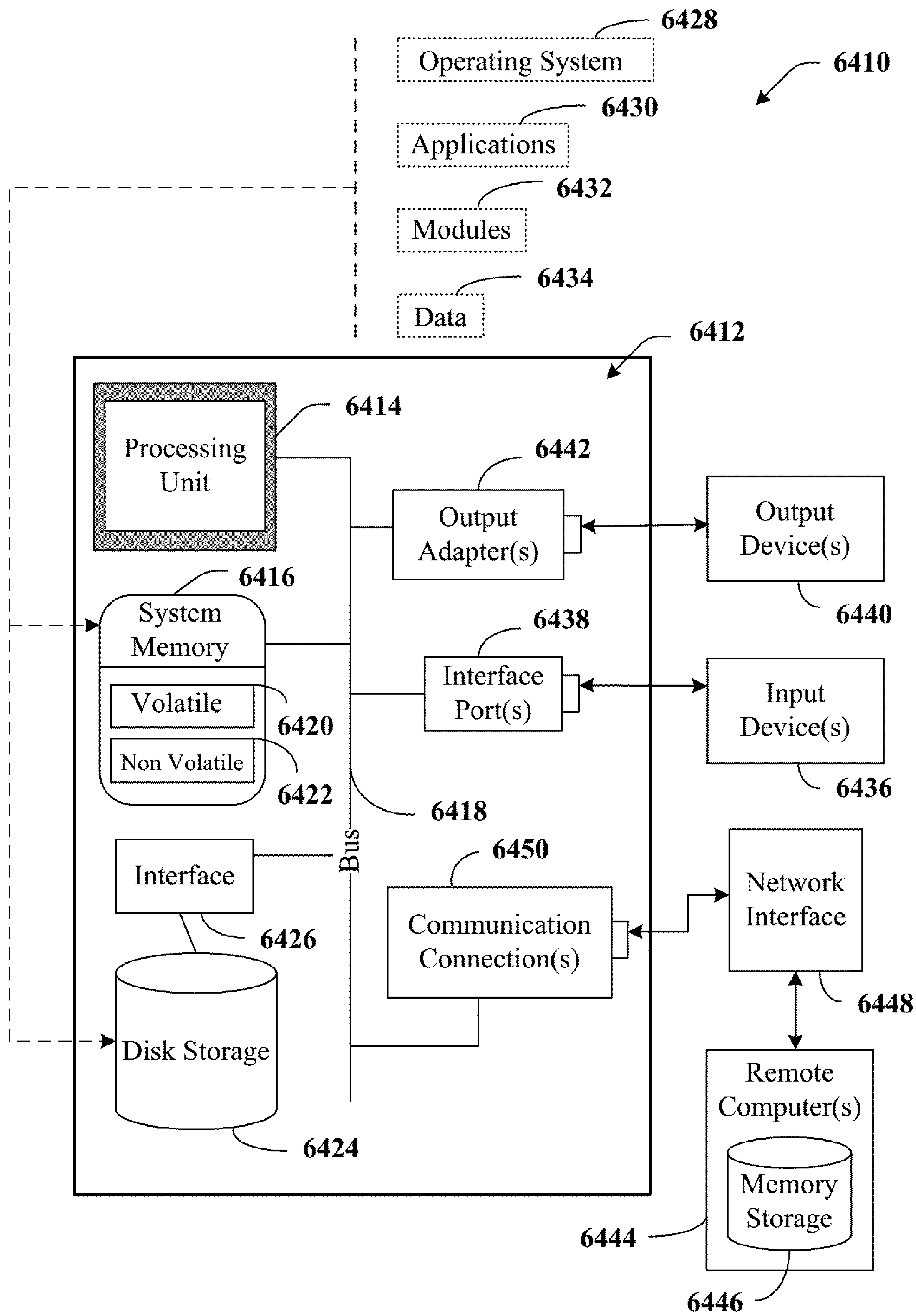

6428
Operating System
6410
6430
Applications
6432
Modules
6434
Data
6412
Processing Unit
6414
6442
Output Adapter(s)
Output Device(s)
6440
6416
System Memory
Volatile
Non Volatile
6420
6422
6438
Interface Port(s)
Input Device(s)
6436
6418
Bus
Interface
6426
Disk Storage
6424
6450
Communication Connection(s)
Network Interface
6448
Remote Computer(s)
Memory Storage
6444
6446

FIG. 64

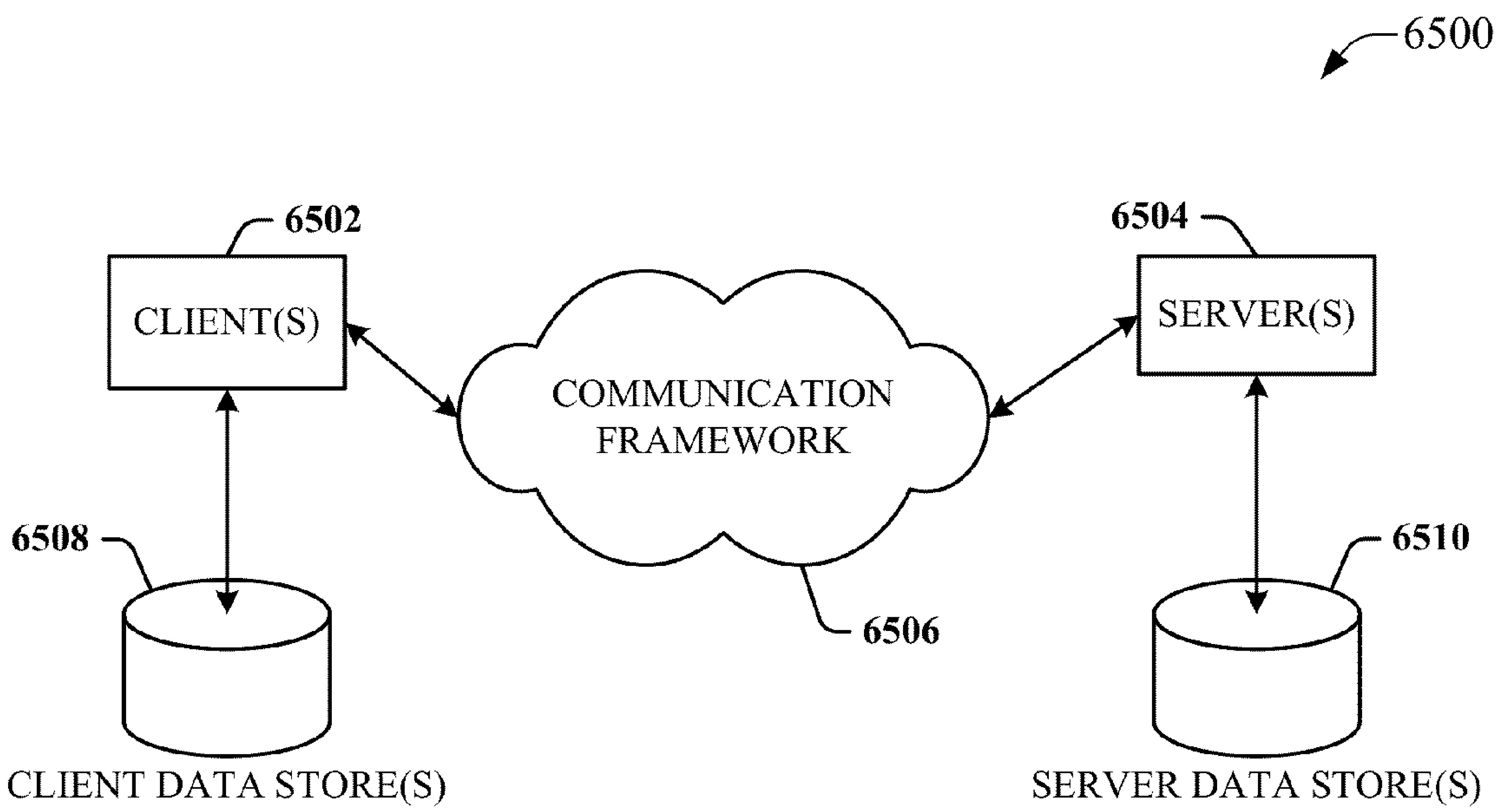

6500
6502
CLIENT(S)
6504
SERVER(S)
COMMUNICATION FRAMEWORK
6508
6510
6506
CLIENT DATA STORE(S)
SERVER DATA STORE(S)

FIG. 65

DEVELOPMENT ENVIRONMENT FOR A SAFETY RELAY CONFIGURATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Ser. No. 61/922,513, filed on Dec. 31, 2013, entitled "SAFETY RELAY CONFIGURATION SYSTEM," the entirety of which is incorporated herein by reference.

BACKGROUND

The subject matter disclosed herein relates generally to configuration systems and graphical interfaces for configuration and monitoring of an industrial safety relay

DESCRIPTION

The following presents a simplified summary in order to provide a basic understanding of some aspects described herein. This summary is not an extensive overview nor is intended to identify key/critical elements or to delineate the scope of the various aspects described herein. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

In one or more embodiments, a system for configuring an industrial safety relay is provided, comprising a configuration component configured to create a configuration program for a safety relay based on configuration input that manipulates one or more graphical function block elements; and a graphical interface component configured to receive the configuration input and to display the one or more graphical function block elements, wherein the graphical interface component is further configured to organize the one or more graphical function block elements into four columns of an editing window.

Also, according to one or more embodiments, a non-transitory computer-readable medium is provided having stored thereon instructions that, in response to execution, cause a system to perform operations, the operations comprising displaying one or more graphical function block elements relating to a configuration program for a safety relay, wherein the displaying comprises organizing the one or more graphical function block elements into four columns of an editing window; and creating a configuration program for a safety relay based on configuration input received via manipulation of the one or more graphical function block elements.

Also, one or more embodiments provide a method for configuring an industrial safety system, comprising displaying, by a system comprising at least one processor, one or more graphical function block elements relating to a configuration program for a safety relay, wherein the displaying comprises organizing the one or more graphical function block elements into four columns of an editing window; and creating, by the system, a configuration program for a safety relay based on configuration input received via manipulation of the one or more graphical function block elements.

To the accomplishment of the foregoing and related ends, certain illustrative aspects are described herein in connection with the following description and the annexed drawings. These aspects are indicative of various ways which can be practiced, all of which are intended to be covered herein. Other advantages and novel features may become apparent from the following detailed description when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a general overview of the relationship between a safety relay configuration system and an industrial safety relay.

FIG. **2** is a block diagram of an example safety relay configuration system that can facilitate configuration, programming, and monitoring of an industrial safety relay.

FIG. **3** illustrates an example screen layout for a device configuration screen of a safety relay configuration system.

FIG. **4** illustrates selection of a device from a list of available devices for inclusion in a project organizer area of the safety relay configuration system.

FIG. **5***a* illustrates the device toolbox area of the safety relay configuration system.

FIG. **5***b* illustrates the device toolbox area of the safety relay configuration system

FIG. **6** illustrates creation of a new project for a selected device on the project organizer area.

FIG. **7** illustrates the areas of a device details area when a project for a selected safety device is open.

FIG. **8** illustrates configuration of a plug-in module for a safety relay configuration project.

FIG. **9** illustrates a graphical representation of a plug-in module in a project window of the safety relay configuration system.

FIG. **10** illustrates a safety logic editor screen of the safety relay configuration system.

FIG. **11** illustrates creation of an example safety relay logic program.

FIG. **12** illustrates an example safety relay logic program.

FIG. **13** illustrates an example Enabling Switch function block.

FIG. **14** illustrates an example Feedback function block.

FIG. **15** illustrates an example Gate Switch function block.

FIG. **16** illustrates an example Light Curtain function block.

FIG. **17** illustrates an example Muting function block.

FIG. **18** illustrates an example Muting function block with Override Settings and Advance Settings expanded.

FIG. **19** illustrates an example Reset function block.

FIG. **20** illustrates an example Restart function block.

FIG. **21** illustrates an example Safety Mat function block.

FIG. **22** illustrates an example Two Hand Control function block.

FIG. **23** illustrates an example Immediate ON function block.

FIG. **24** illustrates an example ON Delay function block.

FIG. **25** illustrates an example OFF Delay function block.

FIG. **26** illustrates an example Jog function block.

FIG. **27***a* illustrates an example Mute function block.

FIG. **27***b* illustrates an example Mute function block with the output address drop-down selected.

FIG. **28** illustrates switching of test pulses to input terminals of a safety relay.

FIG. **29** illustrates three example test pulse schemes supported by the safety relay configuration system.

FIG. **30***a* illustrates an example safety monitoring function block for a dual-channel safety device.

FIG. **30***b* illustrates restriction of available terminals that can be assigned to a test pulse parameter of a function block.

FIG. **30***c* illustrates an example safety monitoring function block for a three-channel safety device.

FIG. **31** illustrates automatic assignment of appropriate test source terminals to a safety monitoring function block.

FIG. **32** illustrates a three-column combo box supported by the safety relay configuration system.

FIG. **33** illustrates a simplified electrical schematic for a safety mat.

FIG. **34** illustrates automatic assignment of unused test sources to a safety mat function block.

FIG. **35** illustrates connection of function block inputs and outputs using signal flow lines.

FIG. **36** illustrates an editing environment that maintains a fixed horizontal distance between function blocks.

FIG. **37***a* illustrates an example Emergency Stop function block in a default presentation.

FIG. **37***b* illustrates an example Emergency Stop function block with advanced settings exposed.

FIG. **38***a* illustrates prevention of assignment of standard-rated input terminals to safety-rated function blocks.

FIG. **38***b* illustrates limitation of standard-rated input terminals only to assignment of non-safety-rated function blocks.

FIG. **39** illustrates an example plug-in expansion module for a safety relay.

FIG. **40** illustrates function block referencing.

FIG. **41** illustrates a development environment in which available memory is represented by function block targets.

FIG. **42** illustrates automatic creation of an input reference container and a signal flow line when a safety monitoring function block is added to a safety relay configuration project.

FIG. **43** illustrates automatic creation of multiple input reference containers and signal flow lines when a safety monitoring function block is added to a safety relay configuration project.

FIG. **44** illustrates automatic creation of multiple input reference containers and signal flow lines when a safety monitoring function block is added to a safety relay configuration project.

FIG. **45** illustrates setting of an input terminal's hardware configuration via a parameter setting on an associated function block.

FIG. **46***a* illustrates automatic creation of output reference containers and associated signal lines when a safety output function block is added to a safety relay configuration project.

FIG. **46***b* illustrates automatic creation of a blank output reference container and associated signal line when a terminal is selected for an output of a safety output function block.

FIG. **47** illustrates a function block with controls that enable configuration of hardware-related behaviors for an assigned terminal.

FIG. **48** illustrates actionable items on a function lock differentiated by color.

FIG. **49** illustrates organization of configuration parameters on a function block using segregated regions.

FIG. **50** illustrates an example function block color and dimensional design.

FIG. **51***a* illustrates automatic configuration of a multi-purpose terminal as a single-wire safety input.

FIG. **51***b* illustrates configuration of a multi-purpose terminal as a normally-closed safety input.

FIG. **52***a* illustrates configuration of a multi-purpose output terminal as a pulse test safety output.

FIG. **52***b* illustrates configuration of a multi-purpose output terminal as a single-wire safety output.

FIG. **53***a* illustrates configuration of a multi-purpose terminal as a safety output with pulse testing.

FIG. **53***b* illustrates configuration of a multi-purpose terminal as a safety output without pulse testing.

FIG. **53***c* illustrates configuration of a multi-purpose terminal as a normally-closed safety input.

FIG. **53***d* illustrates configuration of a multi-purpose terminal as a normally-open safety input.

FIG. **53***e* illustrates configuration of a multi-purpose terminal as a test source.

FIG. **54** illustrates function blocks comprising circular signal flow wiring pins.

FIG. **55***a* illustrates an open address selection combo box for a function block when no expansion I/O is configured.

FIG. **55***b* illustrates addition of expansion I/O to a safety relay using the safety relay configuration system.

FIG. **55***c* illustrates addition of plug-in I/O to a terminal selection combo box.

FIG. **56** illustrates a Global Emergency Stop function block.

FIG. **57** illustrates an address selection combo box that includes a category for Modbus inputs.

FIG. **58** illustrates pre-mapped registers of status information.

FIG. **59** illustrates display of tooltip information when a cursor is hovered over a function block.

FIG. **60** illustrates tracing of safety monitoring functions to a safety output function.

FIG. **61** illustrates a portion of example safety function documentation.

FIG. **62***a* illustrates an example LED configuration interface that can be invoked within the development environment of the safety relay configuration system.

FIG. **62***b* illustrates filtering of available LED configuration options using a type filter setting.

FIG. **63***a* illustrates color-coding of a signal flow line when all required input conditions for an associated safety output function block are satisfied.

FIG. **63***b* illustrates blinking of a safety output function block to indicate that the associated safety circuit is ready to be reset.

FIG. **64** is an example computing environment.

FIG. **65** is an example networking environment.

DETAILED DESCRIPTION

Various aspects of this disclosure are now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It should be understood, however, that certain aspects of this disclosure may be practiced without these specific details, or with other methods, components, materials, etc. In other instances, well-known structures and devices are shown in block diagram form to facilitate describing one or more aspects.

As used in this application, the terms "component," "system," "platform," "layer," "controller," "terminal," "station," "node," "interface" are intended to refer to a computer-related entity or an entity related to, or that is part of, an operational apparatus with one or more specific functionalities, wherein such entities can be either hardware, a combination of hardware and software, software, or software in execution. For example, a component can be, but is not limited to being, a process running on a processor, a hard disk drive, multiple storage drives (of optical or magnetic storage medium) including affixed (e.g., screwed or bolted) or removably affixed solid-state storage drives; an object; an executable; a thread of execution; a computer-executable program, and/or a computer. By way of illustration, both an application running on a server and the server can be a component. One or more components can reside within a process and/or thread of execution, and a component can be localized on one computer and/or distributed between two or more computers. Also, components as described herein can execute from various computer readable storage media having various data structures stored thereon. The components may communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network such as the Internet with other systems via the signal). As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry which is operated by a software or a firmware application executed by a processor, wherein the processor can be internal or external to the apparatus and executes at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts, the electronic components can include a processor therein to execute software or firmware that provides at least in part the functionality of the electronic components. As further yet another example, interface(s) can include input/output (I/O) components as well as associated processor, application, or Application Programming Interface (API) components. While the foregoing examples are directed to aspects of a component, the exemplified aspects or features also apply to a system, platform, interface, layer, controller, terminal, and the like.

As used herein, the terms "to infer" and "inference" refer generally to the process of reasoning about or inferring states of the system, environment, and/or user from a set of observations as captured via events and/or data. Inference can be employed to identify a specific context or action, or can generate a probability distribution over states, for example. The inference can be probabilistic—that is, the computation of a probability distribution over states of interest based on a consideration of data and events. Inference can also refer to techniques employed for composing higher-level events from a set of events and/or data. Such inference results in the construction of new events or actions from a set of observed events and/or stored event data, whether or not the events are correlated in close temporal proximity, and whether the events and data come from one or several event and data sources.

In addition, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise, or clear from the context, the phrase "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, the phrase "X employs A or B" is satisfied by any of the following instances: X employs A; X employs B; or X employs both A and B. In addition, the articles "a" and "an" as used in this application and the appended claims should generally be construed to mean "one or more" unless specified otherwise or clear from the context to be directed to a singular form.

Furthermore, the term "set" as employed herein excludes the empty set; e.g., the set with no elements therein. Thus, a "set" in the subject disclosure includes one or more elements or entities. As an illustration, a set of controllers includes one or more controllers; a set of data resources includes one or more data resources; etc. Likewise, the term "group" as utilized herein refers to a collection of one or more entities; e.g., a group of nodes refers to one or more nodes.

Various aspects or features will be presented in terms of systems that may include a number of devices, components, modules, and the like. It is to be understood and appreciated that the various systems may include additional devices, components, modules, etc. and/or may not include all of the devices, components, modules etc. discussed in connection with the figures. A combination of these approaches also can be used.

The safety relay configuration systems, software, and graphical interfaces described herein comprise a number of features that facilitate intuitive and simplified configuration of an industrial safety relay. These include features that guide the user through the configuration process using an intuitive sequential procedure that provides feedback and prompts based on user interaction, enforce design consistency throughout the configuration project by intelligently limiting user selections, visually organize configuration and status information in a manner that efficiently utilizes display space and allows the user to quickly evaluate available configuration options, and provides other benefits to be described in more detail herein.

FIG. **1** is a general overview of the relationship between the safety relay configuration system **102** and an industrial safety relay **108**. Safety relay **108** can comprise any suitable industrial safety relay or similar device configured to monitor an industrial safety system and control the ability of an industrial system or machine to start or run based on the monitored statuses of one or more safety devices (e.g., emergency stop buttons, safety mats, light curtains, emergency pull cords, etc.). The safety relay can comprise a number of input terminals for monitoring the status of one or more safety devices, and output terminals that control certain machine states based on the statuses of the safety devices. In an example configuration, power to selected control components of the industrial system or machine can be connected to the machine via the safety relay outputs, and the safety relay **108** can be programmed to close the outputs only when the relevant safety devices are in their respective safe states. To ensure control reliability, the safety relay **108** typically includes a number of integrated self-monitoring features to reduce the possibility of a relay failure and to ensure that the industrial system remains safe in the event of such a relay failure. These integrated safety features can include, for example, redundant circuits, internal monitoring to detect short-circuits between contacts, and other such features.

Safety relay **108** is programmable, allowing the user to configure the function of each input and output terminal and to develop logic that controls the behavior of each relay output based on the states of the safety device inputs. Accordingly, safety relay configuration system **102** is designed to communicate with safety relay **108** and to execute a configuration application that allows the user to configure and program safety relay **108**. Safety relay configuration system **102** can communicate with safety relay **108** using any suitable communication means, including communication via a local connection between the configuration system and the safety relay **108** (e.g., universal serial bus, RS232, etc.), or over a networked connection (e.g., Ethernet, Modbus, Common Industrial Protocol, Controlnet, Devicenet, etc.). In one or more embodiments, safety relay configuration system **102** can also communicate with safety relay **108** remotely via the Internet.

Once communication between the safety relay configuration system **102** and safety relay **108** is established, the configuration system can download configuration data **104** to the safety relay based on configuration and programming input provided to the configuration system by the user. For example, the user can develop safety relay logic within the development environment of the configuration application executed by the configuration system **102**, and download the developed program to safety relay **108**. Additionally, safety relay configuration system **102** can read and display status data **106** from the safety relay **108**. The configuration system can render status data **106** on a graphical environment having a similar structure to the development environment used to create the safety relay logic, allowing the user to monitor the statuses of the input devices and relay outputs within the logic environment.

FIG. **2** is a block diagram of an example safety relay configuration system that can facilitate configuration, programming, and monitoring of an industrial safety relay. Aspects of the systems, apparatuses, or processes explained in this disclosure can constitute machine-executable components embodied within machine(s), e.g., embodied in one or more computer-readable mediums (or media) associated with one or more machines. Such components, when executed by one or more machines, e.g., computer(s), computing device (s), automation device(s), virtual machine(s), etc., can cause the machine(s) to perform the operations described.

One or more embodiments of safety relay configuration system **102** can include a graphical interface component **204**, a communication component **206**, a safety relay configuration component **208**, one or more processors **210**, and memory **212**. In various embodiments, one or more of the components **204-208**, the one or more processors **210**, and memory **212** can be electrically and/or communicatively coupled to one another to perform one or more of the functions of the safety relay configuration system **102**. In some embodiments, components **204-208** can comprise software instructions stored on memory **212** and executed by processor (s) **210**. The safety relay configuration system **102** may also interact with other hardware and/or software components not depicted in FIG. **2**. For example, processor(s) **210** may interact with one or more external user interface devices, such as a keyboard, a mouse, a display monitor, a touchscreen, or other such interface devices.

Graphical interface component **204** can be configured to receive user input and to render output to the user in any suitable format (e.g., visual, audio, tactile, etc.). User input can be, for example, safety relay terminal configuration input, safety device selection input, function block selection and configuration input, user responses to prompts provided by the graphical interface component **204**, or other such data. Communication component **206** can be configured to communicatively interface with the safety relay and exchange data between the relay and the configuration system. Communication between the configuration system and the safety relay can be via a local communication link such as USB, RS232, or the like, or via a remote connection over a network or the Internet.

Safety relay configuration component **208** can be configured to execute a safety relay configuration application having features and graphical interface characteristics to be described in more detail herein. The one or more processors **210** can perform one or more of the functions described herein with reference to the systems and/or methods disclosed. Memory **212** can be a computer-readable storage medium storing computer-executable instructions and/or information for performing the functions described herein with reference to the systems and/or methods disclosed.

FIG. **3** is an example, non-limiting screen layout **302** for a device configuration screen of the safety relay configuration system. The example layout **302** includes a device toolbox area **308**, a user menu and toolbar area **306**, a project organizer area **304**, and a device details area **310**.

The device toolbox area **308** can include a catalog drop-down window **312**. When expanded, catalog drop-down window **312** can display a list of available devices **316** for selection by the user for inclusion in the current project. The list of available devices **316** can be organized according to device type, with each device type displayed as an expandable node. For example, selecting the "Safety" node **314** can reveal a list of available safety relays. In some embodiments, hovering a cursor over one of the devices in the list invokes a pop-up window containing additional information about the selected device. A device from the list of available devices **316** can be added to the project organizer area **304** by double-clicking on the selected device in the list, or by dragging the selected device to the project organizer area **304**. In either case, selection of a device from the list of available devices **316** causes the selected device to appear in the project organizer area **304**, as shown in FIG. **4**. Adding a device to the project organizer area **304** makes that device available for creation of a new project.

FIGS. **5***a* and **5***b* illustrate the device toolbox area **308** in more detail. FIG. **5***a* depicts the list of available devices with each device category node collapsed. When one of the category nodes is selected, the available devices under the selected category are expanded and displayed, as shown in FIG. **5***b*.

Turning now to FIG. **6**, selection of a safety relay or other device within the project organizer area **304** (e.g., a safety relay or other device previously selected from the device toolbox area **308** for inclusion in the project organizer area **304**) creates a new project for the selected device. In the illustrated example, a GSR830 safety relay is to be configured and programmed. Accordingly, a device icon corresponding to this type of safety relay is selected from the project organizer area **304**, which launches a "controller details" view within the device details area **310**. In the present example, a project tab **602** is displayed at the top of the device details area **310**, which corresponds to the new project.

FIG. **7** illustrates the areas of the device details area **310** when a project for a selected safety device is open. Device details area **310** includes a device header **702** containing relevant information about the selected device, including the safety device's identity and connection information. Device toolbar area **704** lists a number of selectable operations and commands. These can include both common operations that pertain to all device types (e.g., upload, download, etc.) and device-specific operations that depend on the type of selected safety device (e.g., safety configure, validate, debug, secure, variables). Device toolbar area **704** can also include flash information, such as a manual for the safety device or on-line help information.

Device graphic view area **706** displays the name of the project and a graphical representation **714** of the selected safety device. If the safety relay configuration system is currently connected to the safety device, the device graphic view area **706** can also display operational status information for the device, such as the current mode of the device (program mode, running, etc.), whether the device is currently faulted, identification of the fault, etc. The user can also switch the mode of the safety relay between program mode and running mode from this area. This area also indicates whether the current project has been verified (e.g., the program has been checked for errors or inconsistencies prior to download), and displays a verification identifier for verified projects.

The user can also add configurations for any plug-in modules installed on the safety relay from the device graphic view area **706**. In some embodiments, this can be performed by right-clicking or otherwise selecting an empty slot on the graphical representation of the safety relay, as illustrated in FIG. **8**. This invokes a pop-up configuration window **802** that allows the user to select a category of the plug-in module (e.g., communication module, digital I/O module, or specialty module), and to select a particular model of the plug-in module within the selected category. Once selected, a graphical representation of the plug-in module appears on the graphical representation of the safety relay, as illustrated in FIG. **9**.

Returning now to FIG. **7**, device tree area **612** provides navigation to various configurable aspects of the selected safety device, including but not limited to the communication ports of the safety relay, the devices visual indicators (e.g., LEDs or other indicators), embedded inputs and outputs, and any plug-in modules that are attached to the safety relay (e.g., expansion I/O modules).

Device configuration property pane **610** allows the user to view and edit the current configuration of the selected safety relay. When the user selects an item from the device tree area **612**, the device configuration property pane displays detailed configuration information for the selected item.

Selection of a logic editor button on the device toolbar area **604** launches a safety logic editor, as illustrated in FIG. **10**. In some embodiments, the safety logic editor will be opened in a new tab **1006**. In the illustrated example, a toolbox area **1004** containing selectable safety functions is located on the left-hand side of the screen, and a safety logic editor toolbar **1002** is located across the top of the window. The safety logic editor pane **1010** allows the user to create, view, and edit safety logic and configuration data for the safety relay associated with the current project. In FIG. **10**, the safety logic editor pane **1010** is depicted in its blank state, which is presented to the user when a new project is created. As will be described in more detail herein, the safety relay configuration system allows the user to build safety logic programs for the safety relay by adding function blocks to available memory spaces **1008** on the safety logic editor pane **1010**.

As illustrated in FIG. **10**, the safety logic editor pane **1010** comprises a grid of four columns—Safety Monitoring, Logic Level A, Logic Level B, and Safety Outputs—with each column comprising a number of available memory spaces **1008**. Function blocks can be added to the respective memory spaces **1008** by selecting the function blocks from the toolbox area **1004**. Function blocks can be organized within the toolbox area **1004** according to device type, logic function, safety monitoring function, or other suitable categories. The categories can be displayed as nodes within toolbox area **1004**, such that selection of a node expands the selections available within the selected category.

The Safety Monitoring column of the safety logic editor pane **1010** will typically contain function blocks corresponding to safety input devices to be monitored by the safety relay (e.g., gate switches, light curtains, safety mats, emergency stop buttons, pull cords, etc.). The Logic Level A and B columns are used to contain logical operations that act on the safety inputs in a manner determined by the user in order to control how the safety inputs control that states of the safety outputs. The Safety Output column will typically contain function blocks corresponding to safety outputs of the safety relay. As will be described in more detail herein, the safety relay configuration system allows each function block to be configured directly on the function block graphic, and allows the user to draw connection lines between function block inputs and outputs in order to build a complete safety relay program that can be downloaded to and executed on the safety relay.

An example workflow is now described with reference to FIG. **11** in order to provide a general overview of the process for building safety relay programs according to one or more embodiments. In this example, a gate switch is to be monitored by the safety relay, and the user is to develop logic for controlling a safety relay output based on the monitored status of the gate switch. Accordingly, a Gate Switch function block **1102** selected from the Safety Monitoring Functions tree of the toolbox area and dragged to an available memory space of the safety monitoring column of the safety logic editor pane **1010**. As will be described in more detail herein, the safety relay configuration system automatically assigns to available (unused) input terminal addresses **1110** to the Gate Switch function block **1102** when the function block is added to the program. If desired, these input terminal addresses can be changed if the user wishes to assign different input terminals to the Gate Switch function block **1102**. Other configuration settings for the Gate Switch function block **1102** can be set through interaction with the Gate Switch function block **1102**, as will be described in more detail herein.

Next, the user selects a Safety Output function block **1108** from the Safety Output Functions tree of the toolbox area and drags this function block to an available memory space of the Safety Outputs column of the safety logic editor pane **1010**. Similar to the Gate Switch function block **1102**, the safety relay configuration system will automatically assign two available (unused) safety relay output terminal addresses **1112** to the Safety Output function block **1108**. These output addresses can be changed by the user if desired through interaction with the function block on the editor pane. Other configuration settings for the Safety Output function block **1108** can be set through interaction with the function block. For example, the Reset Type for the Safety Output function block **1108** can be changed from Manual to Automatic by selecting the appropriate setting from a drop-down box on the function block.

In this example, no logical operators are to be performed on the gate switch status, but instead the safety output is to be directly controlled by the status of the gate switch. Accordingly, the user can directly connect the output of the Gate Switch function block **1102** to the input of the Safety Output function block **1108**. This can be performed, for example, by clicking on the input of the Safety Output function block **1108** (which is colored blue to indicate that no connection has yet been made), then clicking on the output of the Gate Switch function block **1102** (similarly colored blue when no connection is yet made). In response to these selections, the safety relay configuration system automatically creates two Pass Through blocks between the Gate Switch and Safety Output function blocks in the Logic Level A and B columns, respectively, and draws a connection line between the two function blocks through the two Pass Through blocks. The Pass Through blocks perform no logical functions, but merely pass status information, unchanged, from their inputs to their outputs.

Once the logic program is completed, the user can compile and download the program to the safety relay by selecting appropriate controls on the device toolbar area **604**.

FIG. **12** illustrates another example logic program according to one or more embodiments. In this example, the safety monitoring column contains three safety monitoring blocks corresponding to three safety input devices—a Gate Switch function block **1202**, an Emergency Stop function block **1210**, and a Reset function block **1214**. Each of the safety monitoring function blocks have been assigned to selected input terminals of the safety relay using address windows **1216**, **1218**, and **1220**. The outputs of Gate Switch function block **1202** and Emergency Stop function block **1210** have been connected to respective two inputs of an AND function block **1204** in the Logic Level A column. The AND function block generates a high signal on its output when the outputs of the Gate Switch function block **1202** and the Emergency Stop function block **1210** are both ON. The output of the AND function block **1204** is connected to the input of an Immediate OFF function block **1208** in the Safety Output column, via a Pass Through function block **1206**. The Safety Output column controls two output terminals of the safety relay—designated in address window **1222**—based on the output of the AND function block and the configuration settings specified by the user on the function block **1208**.

The output of the Emergency Stop function block **1210** is also connected to an OFF Delay function block **1212** in the Safety Output column (via two Pass Through function blocks). By this configuration, the OFF Delay function block **1212** controls the output terminal designated in the address window **1224** based on the output of the Emergency Stop function block **1210**.

Reset function block **1214** has been designated an available input terminal address in address window **1220**, and has been linked to the Immediate OFF function block **1208** by reference using the Reset Input window **1226** on the Immediate OFF function block **1208**. In this way, the Reset function block **1214**, controlled by input address specified in **1220**, is configured to reset the Immediate OFF function block **1208**.

In addition to development, the safety logic layout depicted in FIG. **12** can also be used to monitor the safety relay logic during runtime after the logic has been downloaded to the relay. During runtime monitoring, live status information corresponding to the respective safety monitoring devices and outputs can be overlaid over their respective function blocks. Additionally, the function blocks can include color animation that changes the color of the function blocks based on their respective current statuses.

FIGS. **13-22** depict a number of example safety monitoring function blocks (SMFs) that are available in one or more embodiments of the safety relay configuration system. It is to be appreciated that various embodiments of the safety relay configuration system may include all described safety monitoring function blocks, or only a subset of the function blocks described herein. Additional function blocks not described herein may also be included in one or more embodiments without deviating from the scope of this disclosure.

FIG. **13** illustrates an example Enabling Switch function block **1302**, which monitors the states of two input channels (designated in address window **1304**) and turns on its output when both inputs are in the active states. The Enabling Switch function block **1302** turns the output off when either one or both of the input channels returns to the Safe state. Both input channels for the Enabling Switch instruction are normally open. This means zeros on both channels represent the Safe state, and ones on both channels represent the Active state. The Enabling Switch function block **1302** generates a fault if the input channels are in an inconsistent state (e.g., one Safe and one Active) for more than the specified discrepancy time, set in the discrepancy time window **1312**.

Test Source windows **1306** assign the test sources that are to source the 24V test pulses for channels A and B, respectively. These test pulses are used to detect shorts to **24**B and channel-to-channel shorts to other inputs, as will be described in more detail herein.

The Inputs window **1308** toggles the function block **1302** between dual normally closed (NC), dual output signal switching device (OSSD), and single inputs. The Pulse Testing window **1310** defines whether Test Pulsing is enabled on the input channels. If the Pulse Testing window **1310** is enabled, the Test Source windows **1306** will be made available for editing.

When an input filter time is specified in the input filter time window **1314**, for the specified length of time, an input channel is allowed to go to the Safe state while the other channel is in the Active state without the output of the function block **1302** going to its Safe state. However, the output will transition to the Safe state when both input channels are in the Safe state at the same time.

FIG. **14** illustrates an example Feedback function block **1402**. The input of the Feedback function block **1402** is constantly monitored to ensure it reflects the state of its associated Safety Output function. When the associated Safety Output function transitions, the Feedback function block monitors the input to determine whether the input has transitioned within a configured Feedback Reaction time. The Feedback function block **1402** may include multiple inputs for monitoring respective multiple Safety Output functions. The number of inputs can be set using the Inputs window **1406**. The value set in the Input Filter window **1408** determines the On/Off delay for the input signal. Setting the input filter can reduce the influence of chattering and external noise.

FIG. **15** illustrates an example Gate Switch function block **1502**, which includes inputs—**1504***a* and **1504***b*—for respective two channels from the gate switch device. Test Source windows **1506** assign the test source that is to source the 24V test pulses for channels A and B, respectively, similar to previous examples. Gate Switch function block **1502** also includes an Inputs window **1508**, a Pulse Testing window **1510**, a Discrepancy Time window **1512**, and an Input Filter window **1514**, which perform similar functions to the corresponding windows of previously described function blocks.

FIG. **16** illustrates an example Light Curtain function block **1602**, which includes two inputs—**1604***a* and **1604***b*—corresponding to respective two channels from a light curtain. Light curtain function block **1602** also includes an Inputs window **1606**, a Pulse Testing window **1608**, a Discrepancy Time window **1610**, and an Input Filter window **1612**, which perform similar functions to the corresponding windows of previously described function blocks. The Light Curtain function block **1602** is depicted with pulse testing disabled, which causes the Test Source windows (e.g., Test Source windows **1506** of FIG. **15**) to be invisible.

FIG. **17** illustrates an example Muting function block **1702**. The Muting function block **1702** occupies one row when added to the safety editor project, and controls muting of a light curtain corresponding to a defined Light Curtain function block. Light curtain inputs **1704***a* and **1704***b* correspond to the two channel inputs of the light curtain. Muting sensor inputs **1706***a* and **1706***b* correspond to the muting sensor inputs from the light curtain. For 2-sensor configurations, Sensor **1** (S**1**) must be the first sensor to be blocked and the last to be cleared in the muting sequence, while Sensor **2** (S**2**) must be the second sensor to be blocked and the first to be cleared in the muting sequence. Additional sensor inputs can be enabled by switching the Mute Type window **1708** from 2 -sensor type to 4-sensor type (Mute Type window **1708** can also allow selection between 2-sensor T-type and 2-sensor L-type). For such 4-sensor configurations, when material is moving in the forward direction, S**1** must be the first sensor to be blocked and cleared, S**2** must be the second sensor to be blocked and cleared, S**3** (not shown) must be the third sensor to be blocked and cleared, and S**4** (not shown) must be the fourth sensor blocked and cleared. When material is moving in the reverse direction, S**1** must be the fourth sensor to be blocked and cleared, S**2** must be the third sensor to be blocked and cleared, S**3** must be the second sensor to be blocked and cleared, and S**4** must be the first sensor to be blocked and cleared.

The Sensor Synch Time window **1710** configures the maximum amount of time allowed between clearing or blocking of the muting sensor inputs before generating a fault. The Max Mute Time window **1716** specifies the maximum amount of time during which the Muting function block **1702** lets the protective function of the light curtain be disabled before generating a fault.

Additional settings can be viewed by selecting either the Override Settings drop-down **1712** or the Advanced Settings drop-down **1714**. FIG. **18** illustrates Muting function block **1702** with the Override Settings and Advance Settings expanded.

Override Settings include an Override window **1802** that, when enabled, allows a temporary bypass of the muting instruction's function. The Max Override Time window **1804** specifies the amount of time the instruction lets the override feature energize the output of the instruction. The Inputs window **1806** defines the number of input channels for the Override switch. The Pulse Testing window **1808** defines whether the inputs for the Override switch are to be pulse tested. The Test Source A window **1810** and Test Source B window **1812** assign a test source for sourcing the 24V pulse testing for each channel of the override switch.

The Advanced Settings can include a Light Curtain Discrepancy Time window **1814** that sets the amount of time that the light curtain or the override switch inputs are allowed to be in an inconsistent state before an instruction fault is generated.

When an input filter time is specified in the Muting Sensors Input Filter window **1816**, an input channel of the muting sensor is allowed to go to the Safe state for the specified length of time while the other channel is in the Active state without the output of the instruction going to its Safe state. However, the output will go to the Safe state when both input channels are in the safe state at the same time. Light Curtain Input Filter window **1818** and Override Input Filter window **1820** are similar settings for the light curtain input channels and override input channels, respectively.

FIG. **19** illustrates an example Reset function block **1902**, which monitors a reset signal on the terminal specified in the address window **1906**, and energizes its output on the falling edge of the monitored signal. The Reset function block **1902** is used in safety functions requiring a manual intervention to turn the safety system on. The Input Filter window **1904** sets the On/Off delay for the input signal, which can help reduce the influence of chattering and external noise.

FIG. **20** illustrates an example Restart function block **2002**. The Restart function block **2002** typically works in conjunction with an AND or OR logic lock in Logic Level A or Logic Level B. When all inputs are satisfied, exercising the Restart function block's input **2004** will cause the restart function to be effective. The Input Filter window **2006** sets the On/Off delay for the input signal.

FIG. **21** illustrates an example Safety Mat function block **2102**. The output of Safety Mat function block **2102** indicates whether the corresponding safety mat is occupied. The two inputs correspond to the two channels, respectively, of the safety mat. The Test Source A window **2104** and Test Source B window **2106** designate the test sources that provide the 24V test pulses for the Safety Mat for detection of shorts to 24V and channel-to-channel shorts to other inputs on the safety relay. Discrepancy Time window **2108** designates the time that the instruction uses to determine the difference between a short circuit and a pressure on the safety mat.

When an input filter time is entered in the input filter window **2110**, an input channel is allowed to go to the Safe state for the designated length of time while the other channel is in the Active state without the output of the function block **2102** going to its Safe state. The output will go to the safe state, however, when both input channels are in the safe state at the same time.

FIG. **22** illustrates an example Two Hand Control function block **2202**, which is used in conjunction with two-handed actuation controls. In particular, FIG. **22** illustrates the Two Hand Control function block **2202** when 2 N.C./N.O. is selected in the Input window **2208**. In this mode, the Two Hand Control function block **2202** has two pairs of inputs **2214** and **2216**, with each pair comprising a normally open input (**2214*a*** and **2216*a***) and a normally closed input (**2214*b*** and **2216*b***). Alternatively, if the Input window **2208** is set to 2 N.O. mode, only one pair of normally open inputs will be shown on the function block.

In 2 N.C./N.O mode, input **2214*a*** corresponds to the normally open contact for the right button of the two-handed control, input **2214*b*** corresponds to the normally closed contact for the right button, input **2216*a*** corresponds to the normally open contact for the left button, and input **2216*b*** corresponds to the normally-closed contact for the left button. In 2 N.O. mode, only two inputs will be available on the function block, corresponding to the normally open contacts for the right and left buttons, respectively.

Test Source A window **2204** and Test Source B window **2206** assign the test sources that are to provide the 24V pulses for input channels A and B, respectively, for detection of shorts to 24V or channel-to-channel shorts to other inputs on the safety relay.

The Pulse Testing window **2210** sets whether test pulsing is enabled on the input channels. The Test Source A and B windows will only appear on the function block **2202** if the Pulse Testing window is set to "Enabled."

When an input filter time is specified in the Input Filter window **2212**, an input channel of the function block is allowed to go to the Safe state for the specified length of time while the other channel is in the Active state without the output of the function block **2202** going to its Safe state. The output of the function block will go to the Safe state when both input channels are in the Safe state at the same time.

FIGS. **23-27** depict a number of example safety output function blocks (SOFs) that are available in one or more embodiments of the safety relay configuration system. It is to be appreciated that various embodiments of the safety relay configuration system may include all described safety output function blocks, or only a subset of the function blocks described herein. Additional function blocks not described herein may also be included in one or more embodiments without deviating from the scope of this disclosure

FIG. **23** illustrates an example Immediate ON function block **2302**, which can monitor a single logical input **2310** and activate one or more field outputs when the following conditions are met: (1) When the Reset Type window **2306** is set to Manual Reset, the logical input **2310** is in the Active State and the Reset Input is transitioned from a zero to a one and back to zero within a defined time (e.g., 250 ms), or (2) When the Reset Type window is set to Automatic Reset, the logical input **2310** is in the Active state.

The Immediate ON function block **2302** also monitors a feedback channel for the field outputs (which can be specified in Feedback window **2304**) and generates a fault if the channels do not indicate the desired state of the associated outputs within a defined time (e.g., 150 ms). The feedback will typically be measured from a device either directly or indirectly controlled by the output of the instruction.

The Monitored Input window **2308** is only visible of the Reset Type window **2306** is set to "Manual," and sets the output of the function block Active after the monitored logical input signal transition from the Safe state to the Active state, and the Reset input transitions from a zero to a one and back to a zero within a defined time (e.g., 250 ms).

FIG. **24** illustrates an example ON Delay function block **2402**, which monitors a single logical input **2412** and activates one or more field outputs after a specified time delay when the following conditions are met: (1) If the Reset Type window **2408** is set to Manual, the logical input **2412** is in the Active state, the Reset input is transitioned from a zero to a one and back to a zero within a defined time (e.g., 250 ms), or (2) if the Reset Type window **2408** is set to Automatic, the logical input **2412** is in the Active state.

The ON Delay function block **2402** also monitors a feedback channel for the field outputs (defined in the Feedback window **2404**) and generates a fault if the channels do not indicate the desired state of the associated outputs within a defined time (e.g., 150 ms). The feedback is typically from a device either directly or indirectly controlled by the output of the function block **2402**.

The Time Delay window **2406** specifies how long to delay activating the output of the function block **2402** after the logical input signal transitions from the Safe state to the Active state and, if Manual reset is enabled, the reset input transitions from a zero to a one and back to a zero.

The Reset Input window **2410** is visible only if Manual reset is enabled, and sets the output Active after the monitored logical input signal transitions to the Active state, and the Reset input transitions from a zero to a one and back to a zero within a defined time (e.g., 250 ms).

FIG. **25** illustrates an example OFF Delay function block **2502**, which monitors a single logical input **2514** and activates one or more field outputs after a specified time delay and when the following conditions are met: (1) If the Reset Type window **2510** is set to Manual, the logical input **2514** is in the Active state, the Reset input is transitioned from a zero to a one and back to zero within a defined time (e.g., 250 ms), or (b) If the Reset Type window **2510** is set to Automatic, the logical input **2514** is in the Active state.

The OFF Delay function block **2502** also monitors a feedback channel for the field outputs (specified by the Feedback window **2504**) and generates a fault if the channels do not indicate the desired stat of the associated outputs within a defined time (e.g., 150 ms). The feedback is typically from a device that is either directly or indirectly controlled by the output of the function block **2502**.

The Time Delay window **2506** sets how long to delay transitioning the output of the function block **2502** after the logical input signal transitions form the Active state to the Safe state.

When the Retriggerable window **2508** is set to Enabled, the Time Delay to transition the output of the function block **2502** will be cancelled should the logical input signal transition from the Safe state back to the Active state, and the output will remain in the Active state. If this window is set to Disabled, once the time delay has begun timing, it cannot be reset.

The Reset Input window **2512** sets the monitored reset input. This window is only visible if the Reset Type is set to Manual.

FIG. **26** illustrates an example Jog function block **2602**. When the Reset Type window **2610** is set to Manual, the output of the Jog function block **2602** is activated when the logical input **2614** is in the Active state and the reset input is transitioned from a zero to a one and back to zero within a defined time (e.g., 250 ms). When the Reset Type window **2610** is set to Automatic, the output is set when the logical input **2614** is in the Active state. The output of the Jog function block **2602** will remain active until the jog time of the function block is expired.

The Jog Time window **2606** sets the time for which the output of the Jog function block will stay in the Active state after the logical input **2614** transitions from the Active state to the Safe state and, in the case of Manual reset, the reset input transitions from a zero to a one and back to zero.

The Feedback window **2608** specifies the feedback from a device either directly or indirectly controlled by the output of the Jog function block **2602**.

The Reset Input window **2612** sets the monitored reset input, and is only visible when the Reset Type is set to Manual. In Manual reset mode, the output is set Active after the monitored logical input **2614** transitions from the Safe state to the Active state, and the Reset input transitions from a zero to a one and back to a zero within a defined time (e.g., 250 ms).

FIGS. **27***a* and **27***b* illustrate an example Mute function block **2702**, which is configured to monitor a Mute safety monitoring function block specified by Mute SMF window **2704**. When the protective function of the light curtain is disabled (muted) for the corresponding Mute safety monitoring function specified by Mute SFM window **2704**, the output of the Mute function block **2702** will be enabled. As illustrated in FIG. **27***b*, when the output address drop-down **2706** is selected, only SMFs that are configured as mute functions will be displayed for user selection.

The graphical interface for the safety relay configuration system includes a number of features intended to provide an intuitive development environment and simplify the relay configuration workflow. These features include, but are not limited to, guiding the user through the process of creating an error-free and internally consistent relay configuration application by limiting user choices at certain selection steps, providing wizards that explain configuration steps and minimize tool training time, arranging function blocks on the development window in a linear, organized fashion, and other such aspects. Various graphical interface features for the safety relay configuration system are now described in connection with FIGS. **28**-**63**. Although these features are discussed individually in the following description, it is to be appreciated that some embodiments of the present disclosure may include only one of the described features, a combination of two or more of the described features, or all of the described features without departing from the scope of this disclosure.

As noted above, some safety relays are designed to generate test outputs that can be used in combination with a safety input to detect short-circuits or cross-channel faults. As illustrated in FIG. **28**, when an external input contact of a safety relay **2802** is closed on an electro-mechanical safety device, a 24V test pulse is output from the test output terminal to facilitate diagnosis of field wiring and input circuitry. Using this function, short-circuits between input terminals and 24V power, or between input signal lines and open circuits, can be detected. In the illustrated example, test source output terminal T**0** provides a test pulse to input terminal IN**0** to facilitate detection of a short-circuit between input terminal IN**0** and 24V power source terminal IN+. Likewise, test source output terminal T**1** provides 24V test pulses to input terminal IN**1** to facilitate detection of a short-circuit between input terminals IN**1** and IN**0**.

In order to support dual-channel and triple-channel electro-mechanical safety devices, the safety relay **2802** can support up to three unique pulsing schemes to ensure that a cross fault between any two (or three) channels can be detected. In some embodiments, these three unique pulsing schemes can comprise respective 24V pulse trains that are out of synch with one another, as illustrated in FIG. **29**. In this way, the safety relay can identify which of the three pulse schemes—Type A, Type B, or Type C—is being seen by a particular input terminal, and confirm that the terminal is receiving the expected test pulse. The safety relay can also determine whether application of a test pulse on a first input terminal causes the same test pulse to be detected on a different input terminal, indicating a short between the two terminals.

One or more embodiments if the safety relay configuration system can intelligently manage the test output pulse test type to ensure that every electro-mechanical safety device in the system has a unique pulsing scheme for each of the safety device's channels. This feature is illustrated in FIGS. **30***a* and **30***b*. FIG. **30***a* illustrates an example safety monitoring function block **3002** for a dual-channel safety device. Function block **3002** includes to Test Source windows—Test Source A **3004***a* and Test Source B **3004***b*—which allow the user to select the two test sources (unique test pulsing schemes) to be assigned to the respective two channels of the device. All safety monitoring functions for dual-channel safety devices will include these two Test Source windows (function blocks for three-channel devices will include three such Test Source assignment windows, as illustrated in FIG. **30***c*). The terminal assigned to Test Source A (terminal **12** in FIG. **30***a*) takes on the test output Type A pulsing scheme, while the terminal assigned to Test Source B (terminal **13** in FIG. **30***a*) takes on the test output Type B pulse scheme.

Once a pulsing scheme has been assigned to a terminal on a safety monitoring function block, that terminal can only be used on test sources that have the same Type label throughout the rest of the project. That is, since terminal **12** has been assigned to Test Source A on function block **3002**, terminal **12** can henceforth only be used for other Test Source A assignments, since a given terminal cannot be assigned to two different pulse schemes. Since assignment of two different pulse schemes to the same terminal would result in a program error, the safety relay configuration system can prevent the user from inadvertently assigning two different pulse schemes to a terminal by intelligently limiting the available terminal selections on other function blocks in the project. For example, as shown in FIG. **30***b*, when the user selects the Test Source A window **3008** on a different function block **3006**, a drop-down selection menu **3010** is displayed. Selection menu **3010** displays available multi-purpose terminals, allowing the user to select a terminal to be assigned to Test Source A. However, terminal **13** is made unavailable for selection (grayed out) on selection menu **3010**, and thus cannot be assigned to Test Source A, since terminal **13** has already been assigned to Test Source B on function block **3002**. Only unassigned terminals or terminals that have previously been assigned to Test Source A are made available on selection menu **3010**. In this way, the safety relay configuration system forces the user to remain consistent with previous test source assignments, preventing assignment of two different sources to the same terminal.

In a related aspect, one or more embodiments of the safety relay configuration system can automatically assign appropriate test source terminals to a safety monitoring function block when the function block is added to the project in the editing environment. For example, as illustrated in FIG. **31**, terminals **12** and **13** have been assigned to Test Source A and B, respectively of safety monitoring function block **3102**. These terminals may have been selected by the user, or may have been automatically assigned by the configuration system when function block **3102** was added based on the availability and suitability of terminals **12** and **13**. Since terminals **12** and **13** have been assigned to function block **3102**, each additional function block designed to monitor a dual-channel electro-mechanical safety device—e.g., function block **3104**—will automatically have terminals **13** and **13** assigned to their Test Source A and Test Source B windows when the function block **3104** is added to the project.

In another aspect, one or more embodiments of the safety relay configuration system support organized multi-column combo boxes (or terminal selection graphic window) that organizes the set of available terminals into three or more columns, as illustrated in FIG. **32**. Conventional combo boxes typically have only a single column drop-down that limits the number of options that can be displayed on the screen. By contrast, the safety relay configuration system disclosed herein can utilize a three-column terminal selection window graphic with organization section bands for differentiating between groups of options in the combo box. The terminal selection window graphic segregates the set of available terminals according to two or more terminal categories to yield respective two or more terminal groups, and the two or more terminal groups comprise respective title bars displaying respective names of the two or more terminal categories. The two or more terminal categories can comprise at least one of embedded safety inputs, multi-purpose terminals, expansion module inputs, networked inputs, or other suitable categories. In example illustrated in FIG. **32**, a user has selected an input of a safety monitoring function block, so that an input terminal of the safety relay can be assigned to the selected function block input. Selection of the input causes a combo box **3210** to be display, which allowed the user to select an input terminal to be assigned to the function block input. Combo box **3210** contains three separate groups of terminals corresponding to different categories of terminals, which are suitably labeled using organization section bands **3204**, **3206**, and **3208**. The organizational section bands also serve to separate the terminal groups. The terminals are organized into three columns to allow more terminals to be displayed than would be possible with a single-column. In the illustrated example, the first group of terminals (labeled with organization section band **3204**) comprises embedded safety inputs, which are integrated safety input terminals of the safety relay. The second group of terminals (labeled with organization section band **3206**) comprise multi-purpose terminals, which are integrated terminals of the safety relay which can be flexibly configured as needed. The third group of terminals (labeled with organization section band **3208**) comprise plug-in inputs, which are input terminals off a plug-in expansion module that was added to the safety relay.

Also, one or more embodiments of the safety relay configuration system can support intelligent test source assignments for safety mat monitoring function blocks. FIG. **33** illustrates a simplified electrical schematic for a safety mat **3302**. Safety mats typically consist of two conductive plates held apart by non-conductive separators. Each conductive plate—channel A and channel B of the safety mat—are alternately sourced by test sources of safety relay **3304**. Test source T**2** and Test Source T**3** of safety relay **3304** are routed through channels A and B of safety mat **3302**, and then to safety inputs I**0** and I**1** of safety relay **3304**. The act of stepping on safety mat **3302** compresses the separators between the two plates, allowing the plates to make contact and creating a cross between the two channels (represented by switch **3306**). The safety mat monitoring function block of the safety relay configuration system configures the safety relay to monitor for the cross between the channels to determine that the mat is occupied.

This configuration requires a unique pair of test sources to test the two channels, otherwise nuisance faults (cross channel faults) would be injected on other electro-mechanical safety devices that utilize these test sources when the safety mat is occupied. Accordingly, one or more embodiments of the safety relay configuration system can ensure that a unique pair of test sources are used with a safety mat monitoring function block (note that on other types of electro-mechanical safety devices it would be more efficient to re-use test sources). As illustrated in FIG. **34**, when a safety mat function block **3404** is added to the project, the editing environment determines unused test sources and automatically assigns these unused test sources as the test sources for the safety mat function block **3404**. In the illustrated example, since previously-added function block **3402** has been assigned terminals **12** and **13** for its Test Source A and Test Source B, respectively, the safety relay configuration system automatically assigns the next two available test source terminals—**14** and **15**—to Test Source A and Test Source B, respectively, of safety mat function block **3404**. This ensures that the safety mat function block **3404** is assigned a unique pair of test source terminals, thereby preventing cross channel faults.

In another aspect, the safety relay configuration system can provide a function block editing environment that supports signal flow line routing rules that yield easily followed signal flow lines for fixed horizontal distanced function blocks. As illustrated in FIG. **35**, a signal flow line **3502** is typically used to logically tie the output **3504** of one function block to an input **3506** of another function block. In one or more embodiments, the editing environment of the safety relay configuration system can enforce a fixed horizontal distance between function blocks, resulting in columns of function blocks, as illustrated in FIG. **36**. When the X,Y coordinate locations of function blocks are restricted in this fashion, a line drawing rule set can be designed that results in aesthetically consistent, easily followed flow lines throughout the project. For example, the system can enforce a line drawing rule specifying that a first instance of a line break (that is, a 90 degree bend in order to connect to an input on a different horizontal level) within a column must break 90 degrees from horizontal $^{24}/_{25}$ths of the horizontal distance between two columns, while a second instance of a line break in the column must break 90 degrees from the horizontal $^{23}/_{25}$ths of the horizontal distance between the two columns. Such rules will maintain that no wiring connection from two separate output pins will share the same vertical line location on the graphical interface.

In a related aspect, the various organization elements and their spacing on the function block editing environment can have respective fixed widths, allowing a full, completed safety relay configuration to be printable without compression.

Also, as illustrated in FIGS. **37***a* and **37***b*, the function blocks of the safety relay configuration system's editing environment can be expanded and collapsed to facilitate viewing or hiding of safety parameters associated with the function blocks. FIG. **37***a* illustrates an example Emergency Stop function block **3704** in its default presentation. In this default view, only a selected subset of parameters are visible (e.g., the Test Source settings), and the advanced settings hidden. Selecting the Advanced Settings label **3702** on the function block **3704** expands the function block to reveal additional safety parameters that can be configured for the function block, as illustrated in FIG. **37***b*. These aspects can facilitate printing the configuration in a manner that captures all safety-related parameters. Moreover, these aspects allow the user to configure each function block via settings located directly on the function block (rather than on a separate window), and to hide less critical parameters while monitoring of the safety function during runtime.

FIGS. **38***a* and **38***b* illustrate another aspect of the graphical editing environment according to one or more embodiments. According to this aspect, restricts presentation of standard-rated input terminals only to non-safety-rated function blocks. In the present example, a safety-rated Emergency Stop function block **3802** is to be added to a project for a safety relay that includes a non-safety-rated digital I/O plug-in (an expansion module that plugs into the safety relay to add non-safety-rated I/O terminals to the relay, such as digital I/O plug-in **3902** illustrated in FIG. **39**). Clicking on an input terminal assignment window **3806** for the safety-rated function block causes a terminal assignment combo box **3804** to be displayed. However, non-safety-rated terminals of the digital I/O plug-in are not displayed as a valid selection in combo box **3804** for assignment to the input of the safety-rated Emergency Stop function block **3802**, even though such non-safety-rated terminals are available. Instead, only embedded safety inputs and multi-purpose terminals (which are safety-rated) are displayed on combo box **3804** and presented to the user for selection.

However, for function blocks for which a safety-rated terminal is not requires, such as Reset function block **3808** in FIG. **38***b*, the available non-safety-rated plug-in terminals are presented in combo box **3810** for selection by the user and assignment to input **3812** (in addition to the safety-rated terminals, which may also be assigned to the non-safety-rated function block **3808**). By presenting non-safety-rated terminals for selection and assignment only to non-safety-rated function blocks, the configuration system drives the user to apply standard (non-safety-rated) input signals only to function blocks for which there is no requirement for a safety-rated signal.

One or more embodiments of the safety relay configuration system can also reduce the number of signal flow lines on a project by supporting function block references between function blocks. This aspect allows a first function block whose output is acting on another function block located multiple columns adjacent to the first function block to make an association by a combo box selection rather than by creating a signal flow wire that spans multiple columns FIG. **40** illustrates an example of this type of function block referencing. In this example, safety output function block **4004** is linked to the Reset function block **4002** by selecting the name of function block **4002** ("SMF **1**," found in the name bar **4006** of Reset function block **4002**) in the Reset Input window **4008** of safety output function block **4004**. This name-based referencing mitigates the need to create a signal flow line between the Reset function block **4002** and the safety output function block **4004**.

One or more embodiments of the safety monitoring configuration system can also provide a real-time graphical representation of an amount of memory consumed in the function block editor against a total available memory. As illustrated in FIG. **41**, this can be achieved using a memory map in which available memory is represented as individual blank function block targets **4102**. When a function block (e.g., function block **4104**) is assigned to a blank function target, either by dragging-and-dropping the function block **4104** to the target or through other assignment means, the blank target disappears and the selected function block is displayed in its place. The label in the name bar of the function block (SMF **2**) corresponds to the memory location of the function block. The number of available blank function block targets **4102** is analogous to the amount of remaining memory space available for addition of more function blocks. When all blank function block targets **4102** have received a function block assignments, no more function blocks can be added to the project intuitively convey an amount of available memory remaining for addition of function blocks to a project.

In one or more embodiments, when a safety monitoring function block is added to a project, as illustrated in FIG. **42**, an input reference container **4202** and a signal flow line **4204** between the input reference container **4202** and the function block can be automatically created. Automatically adding the input reference container and signal flow line in this manner can reduce the number of steps required to be taken by the user when adding and configuring a function block.

As illustrated in FIGS. **43** and **44**, the number of input reference containers and associated signal lines that are automatically added to a function block is dependent on the number of inputs required by the function block. For example, safety monitoring function block **4302** in FIG. **43** is a two-channel device requiring two input assignments. Accordingly, to input reference containers **4304** and associated signal flow lines are automatically added to the function block. Similarly, safety input function block **4402** requires four inputs (two N.O. and two N.C. inputs), and so the development environment automatically adds four input reference containers **4404** and associated signal flow lines to when function block **4402** is added to the project. In addition, one or more embodiments of the safety relay configuration system can automatically assign available input terminals to the input reference containers when the function block is added.

In another aspect, certain function blocks supported by the safety monitor configuration system can include hardware configuration parameters for input terminals associated therewith. That is, once an input is assigned to a function block, as illustrated in FIG. **45**, the input's hardware configurations can be set via parameter settings on the function block. This can be beneficial for safety relay configurations, since dual-channel safety monitoring functions require two input terminals (e.g., input terminals **4502**) with identical filter times. By including an input filter parameter **4504** on the function block itself, the system enforces application of the same input filter for both terminals.

Similar to the input reference containers, the safety relay configuration system can also automatically create output reference containers and signal flow lines between the output reference containers and the function block when the function block is added to the project. As illustrated in FIG. **46***a*, output reference containers **4604** and associated signal lines are automatically created when function block **4602** is added to the project. In addition, a blank output reference container **4606** and associated signal flow line is added, allowing the user to associate an additional output terminal to the output of safety output function block **4602** if desired. If left blank, this blank output reference container **4606** has no impact on the safety logic. If a terminal selection is made for the blank output reference container **4606**, an additional output reference container **4608** is added, as shown in FIG. **46***b*, and a new blank output reference container **4610** is added.

As illustrated in FIG. **47**, function blocks supported by the configuration system editing environment can include controls that enable not only assignment of an output terminal to an output of a safety output function block **4702**, but also configuration of hardware-related behaviors for the assigned terminal. For example, combo box **4706** allows the user to enable or disable pulse testing for the output terminal assigned in output address container **4704**. Combo box **4706** for configuration of the terminal's hardware characteristics can be dynamically updated to display only valid hardware configurations for the particular terminal selected in output address container **4704**.

As illustrated in FIG. **48**, actionable items on a function block within the logic editor can be differentiated with a distinguishable color to inform the user that the items can be selected or edited.

As illustrated in FIG. **49**, the function blocks supported by the editing environment can be organized such that configuration parameters reside in white-banded regions that span the width of the function block, with grey bars separating selected configurable areas. FIG. **50** is an example, non-limiting function block color and dimensional design. It is to be appreciated, however, that the function block design is not limited to the particular colors and dimensions depicted in FIG. **50**, and that alterations to this design are within the scope of one or more embodiments of this disclosure.

Also, one or more embodiments of the safety relay configuration system can support multi-purpose terminals capable of acting as either a safety-rated input or a single-wire safety input based on the type of safety monitoring function to which the terminal is assigned. For example, as illustrated in FIG. **51***a*, since terminal EI_**10** is assigned to the input of a Single-Wire Safety function block **5002**, the terminal is configured as a single-wire safety input. If terminal EI_**10** is alternatively assigned to the input of a Light Curtain function block **5104**, as illustrated in FIG. **51***b*, the terminal is configured as a normally-closed safety input.

Similarly, the system can also support multi-purpose output terminals capable of acting as safety-rated outputs or single-wire safety outputs depending on the hardware configuration selected for the output terminal on the function block. For example, in FIG. **52***a*, output terminal EO_**21** is configured as a safety output with pulse testing, based on selection of "PT" in corresponding combo box **5204**. If combo box **5204** is alternatively set to "SWS," as illustrated in FIG. **52***b*, output terminal EO_**21** is configured as a single-wire safety output.

In another example, a multi-purpose terminal can be configured to act as either a safety-rated normally-closed input, a safety-rated normally open input, a safety-rated output with pulse testing, a safety-rated output without pulse testing, or as a test pulse terminal depending on either hardware configuration parameters set for the terminal via the function block, or on the particular type of function block to which the multi-purpose terminal is assigned. For example, in FIG. **53***a*, multi-purpose terminal MP_**12** is assigned as an output to a safety output function **5306** by selection of the terminal in output address combo box **5302**, and is configured as a safety output with pulse testing by selection of "PT" (pulse test) in hardware configuration combo box **5304**. In FIG. **53***b*, terminal MP_**12** is alternatively configured as a safety output without pulse testing by selecting "No PT" in combo box **5304**.

In FIG. **53***c*, multi-purpose terminal MP_**12** is configured as a normally-closed safety input when the terminal is assigned to an input of a light curtain safety monitoring function block **5308** using input address combo box **5312**. In FIG. **53***d*, terminal MP_**12** is configured as a normally-open safety input when the terminal is assigned to a normally open (N.O.) input of a Safety Device safety monitoring function block **5310** using input address combo box **5314**. In FIG. **53***e*, multi-purpose input terminal MP_**12** is configured as a test source when the terminal is assigned to Test Source A of safety monitoring function block **5316** using combo box **5318**. Thus, the safety relay configuration system allows a multi-purpose terminal of the safety relay to be easily configured to perform one of multiple functions through assignment and/or configuration of the terminal directly on a function block in the editing environment.

As illustrated in FIG. **54**, each function block can comprise circle-shaped signal flow wiring pins representing input and output points that can be connected on a function block. The circular wiring pins can be inset and located such that the edge of the pin touches the border of the function block. Unassigned pins, such as pin **5402** can be colored differently than pins that have been assigned, such as pin **5404**. For example, unassigned pins can be colored blue, while connected pins can be colored grey.

As noted above, some safety relays supported by the safety relay configuration system described herein can support addition of plug-in expansion modules (see FIG. **39**) configured with additional input and/or output terminals, thereby increasing the number of available terminals for monitoring or output functions. Accordingly, one or more embodiments of the configuration system can automatically map expansion I/O as available terminals in the function block editing environment. This mitigates the need to perform an additional action to map hardware to memory registers before they can be assigned in a logic editor.

To demonstrate this, FIG. **55***a* illustrates an open address selection combo box **5502** for a function block when no expansion I/O is configured (i.e., no expansion plug-in module is configured for the project). Since there is no available expansion I/O, only embedded I/O terminals (embedded safety input terminals and multi-purpose terminals) are displayed in the combo box. To configure expansion I/O corresponding to a plug-in module added to the safety relay, the user can add the expansion I/O to the hardware view, as shown in FIG. **55***b*. Once configured in this manner, the I/O terminals of the plug-in module are made available as valid selections in their own new category in combo box **5502**, as shown in FIG. **55***c*. The act of selecting one of the terminals creates the configuration mapping, as opposed to requiring a separate user action to set up the mapping.

One or more embodiments of the safety relay configuration system can also support a Global Emergency Stop function block. An example Global Emergency Stop function block **5602** is illustrated in FIG. **56**. Any safety output function block—such as function block **5604**—that is enabled to monitor Global Emergency Stop function block **5602** will go to the safe state (OFF) in the event the Global Emergency Stop function block **5602** is not Active (ON). Since most safety applications require an emergency stop, this functionality enables the user to eliminate a logical AND of the emergency stop with other monitored input conditions.

Some embodiments of the safety relay configuration system can also support creation of Modbus input coils that can always be assigned in the safety logic editor. FIG. **57** illustrates an open address selection combo box **5702** that includes a category for Modbus inputs. As a result of this functionality, the user does not have to create the Modbus input registers; rather, the Modbus input registers are always available as selection. The consequence of assigning a coil that is not actually written to by another Modbus device is insignificant, since the coil will always stay at a value of 0, the safe state of the safety relay.

FIG. **58** illustrates pre-mapped registers of status information for all permutations of logic configurable on the safety editor. This is possible because every function block on a safety editor must map to a pre-defined memory location. This memory map is always present in the Modbus map. The consequence of requesting status from a function block register that was never assigned in the editor does not adversely effect the configuration since the function block status will always be off (0).

The safety relay configuration system can also be configured to dynamically change the tooltip that displays when hovering a cursor over a function block based on the state of the function block. For example, information relating to fault conditions associated with a function block while monitoring the safety relay during runtime can be displayed in a tooltip window when the cursor is hovered over the function block, as illustrated in FIG. **59**. Function blocks can also be configured to change red in color in response to detection of a fault condition associated with the function blocks. When the function block is not experiencing an alarm condition, the tooltip can instead display a message indicating the function of the function block.

Also, embodiments of the safety relay configuration system can include an export feature that exports safety configuration logic to a safety function list. In this way, a list of safety functions can be derived from a safety logic configuration created in the logic editor. Since each safety monitoring function represents a monitored safety device on a machine, and each safety output function represents the final control element on a machine, each safety function on the machine can be identified by tracing each safety monitoring function (e.g., safety monitoring function blocks **6002** and **6004** of FIG. **60**) to each safety output function it acts on in the logic configuration (e.g., safety output function block **6006**). The result can be exported by the configuration system, allowing the user to easily document the safety-related functions for their machines. FIG. **61** illustrates a portion of example safety function documentation resulting from the mapping and exporting.

One or more embodiments of the safety relay configuration system can also support configuration of safety relay LED (light emitting diode) indicators. In this way, users can configure LEDs of the safety relay, via the relay configuration system, to enunciate user-defined status conditions. FIG. **62***a* illustrates an example LED configuration interface **6202** that can be invoked within the development environment of the safety relay configuration system. Using this LED configuration interface **6202**, the user can configure one or more LEDs on the safety relay to reflect a user-defined status. To simplify the LED configuration process, the LED configuration interface **6202** includes a Type Filter column **6104** that allows the user, for a given LED, to first select one of several status groupings (e.g., Terminal Status, Safety Monitoring Function Status, Safety Output Function Status, etc.). After a status grouping is selected, a specific list related to the selected status grouping is presented in the corresponding Value combo box **6206**. FIG. **62***b* illustrates an example scenario in which Terminal Status is selected as the Type Filter for LED **0**. Accordingly, when the Value combo box for LED **0** is expanded, a list of terminals **6208** available on the safety relay is displayed. Selection of a terminal from the list of terminals **6208** configures LED **0** to control its state based on the status of the selected terminal. By allowing the user to configure the behavior of individual LEDs on the safety relay, the safety relay configuration system affords a greater degree of flexibility in communicating the status details through the LEDs compared with traditional fixed LED function mapping.

As noted above, the safety relay configuration system can also be used to monitor the safety relay logic during runtime after the relay logic has been developed and downloaded to the safety relay. The monitoring interface can include a number of graphical features that can help the user to quickly assess the current status of the safety system. For example, during runtime monitoring, the system can cause a safety output function block to blink between two different colors (e.g., gray and green) when the safety circuit associated with the safety output function block is in condition to be reset but is awaiting a reset command. This scenario occurs when all required input conditions for the safety circuit are satisfied, but the reset command has not yet been received from the user. As illustrated in FIG. **63***a*, the system can cause the input signal flow line **6302** connected to the input of safety output function block **6304** to turn green when all required input conditions for the safety output function block **6304** are satisfied. The outputs **6306** of safety output function block **6304** remain gray (not energized) since the reset signal has not yet been received. To alert the user that the safety circuit associated with safety output function block **6304** is ready to be reset, the system can cause the function block to blink between two colors (e.g., green and gray) to indicate that a reset is required before the outputs **6306** will energize, as illustrated in FIG. **63***b*.

Embodiments, systems, and components described herein, as well as industrial control systems and industrial automation environments in which various aspects set forth in the subject specification can be carried out, can include computer or network components such as servers, clients, programmable logic controllers (PLCs), communications modules, mobile computers, wireless components, control components and so forth which are capable of interacting across a network. Computers and servers include one or more processors—electronic integrated circuits that perform logic operations employing electric signals—configured to execute instructions stored in media such as random access memory (RAM), read only memory (ROM), a hard drives, as well as removable memory devices, which can include memory sticks, memory cards, flash drives, external hard drives, and so on.

Similarly, the term PLC as used herein can include functionality that can be shared across multiple components, systems, and/or networks. As an example, one or more PLCs can communicate and cooperate with various network devices across the network. This can include substantially any type of control, communications module, computer, Input/Output (I/O) device, sensor, actuator, and human machine interface (HMI) that communicate via the network, which includes control, automation, and/or public networks. The PLC can also communicate to and control various other devices such as I/O modules including analog, digital, programmed/intelligent I/O modules, other programmable controllers, communications modules, sensors, actuators, output devices, and the like.

The network can include public networks such as the internet, intranets, and automation networks such as control and information protocol (CIP) networks including DeviceNet, ControlNet, and Ethernet/IP. Other networks include Ethernet, DH/DH+, Remote I/O, Fieldbus, Modbus, Profibus, CAN, wireless networks, serial protocols, and so forth. In addition, the network devices can include various possibilities (hardware and/or software components). These include components such as switches with virtual local area network (VLAN) capability, LANs, WANs, proxies, gateways, routers, firewalls, virtual private network (VPN) devices, servers, clients, computers, configuration tools, monitoring tools, and/or other devices.

In order to provide a context for the various aspects of the disclosed subject matter, FIGS. **64** and **65** as well as the following discussion are intended to provide a brief, general description of a suitable environment in which the various aspects of the disclosed subject matter may be implemented.

With reference to FIG. **64**, an example environment **6410** for implementing various aspects of the aforementioned subject matter includes a computer **6412**. The computer **6412** includes a processing unit **6414**, a system memory **6416**, and a system bus **6418**. The system bus **6418** couples system components including, but not limited to, the system memory **6416** to the processing unit **6414**. The processing unit **6414** can be any of various available processors. Dual microprocessors and other multiprocessor architectures also can be employed as the processing unit **6414**.

The system bus **6418** can be any of several types of bus structure(s) including the memory bus or memory controller, a peripheral bus or external bus, and/or a local bus using any variety of available bus architectures including, but not limited to, 8-bit bus, Industrial Standard Architecture (ISA), Micro-Channel Architecture (MSA), Extended ISA (EISA), Intelligent Drive Electronics (IDE), VESA Local Bus (VLB), Peripheral Component Interconnect (PCI), Universal Serial Bus (USB), Advanced Graphics Port (AGP), Personal Computer Memory Card International Association bus (PCMCIA), and Small Computer Systems Interface (SCSI).

The system memory **6416** includes volatile memory **6420** and nonvolatile memory **6422**. The basic input/output system (BIOS), containing the basic routines to transfer information between elements within the computer **6412**, such as during start-up, is stored in nonvolatile memory **6422**. By way of illustration, and not limitation, nonvolatile memory **6422** can include read only memory (ROM), programmable ROM (PROM), electrically programmable ROM (EPROM), electrically erasable PROM (EEPROM), or flash memory. Volatile memory **6420** includes random access memory (RAM), which acts as external cache memory. By way of illustration and not limitation, RAM is available in many forms such as synchronous RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM), Synchlink DRAM (SLDRAM), and direct Rambus RAM (DRRAM).

Computer **6412** also includes removable/non-removable, volatile/non-volatile computer storage media. FIG. **64** illustrates, for example a disk storage **6424**. Disk storage **6424** includes, but is not limited to, devices like a magnetic disk drive, floppy disk drive, tape drive, Jaz drive, Zip drive, LS-100 drive, flash memory card, or memory stick. In addition, disk storage **6424** can include storage media separately or in combination with other storage media including, but not limited to, an optical disk drive such as a compact disk ROM device (CD-ROM), CD recordable drive (CD-R Drive), CD rewritable drive (CD-RW Drive) or a digital versatile disk ROM drive (DVD-ROM). To facilitate connection of the disk storage **6424** to the system bus **6418**, a removable or non-removable interface is typically used such as interface **6426**.

It is to be appreciated that FIG. **64** describes software that acts as an intermediary between users and the basic computer resources described in suitable operating environment **6410**. Such software includes an operating system **6428**. Operating system **6428**, which can be stored on disk storage **6424**, acts to control and allocate resources of the computer **6412**. System applications **6430** take advantage of the management of resources by operating system **6428** through program modules **6432** and program data **6434** stored either in system memory **6416** or on disk storage **6424**. It is to be appreciated that one or more embodiments of the subject disclosure can be implemented with various operating systems or combinations of operating systems.

A user enters commands or information into the computer **6412** through input device(s) **6436**. Input devices **6436** include, but are not limited to, a pointing device such as a mouse, trackball, stylus, touch pad, keyboard, microphone, joystick, game pad, satellite dish, scanner, TV tuner card, digital camera, digital video camera, web camera, and the like. These and other input devices connect to the processing unit **6414** through the system bus **6418** via interface port(s) **6438**. Interface port(s) **6438** include, for example, a serial port, a parallel port, a game port, and a universal serial bus (USB). Output device(s) **6440** use some of the same type of ports as input device(s) **6436**. Thus, for example, a USB port may be used to provide input to computer **6412**, and to output information from computer **6412** to an output device **6440**. Output adapters **6442** are provided to illustrate that there are some output devices **6440** like monitors, speakers, and printers, among other output devices **6440**, which require special adapters. The output adapters **6442** include, by way of illustration and not limitation, video and sound cards that provide a means of connection between the output device **6440** and the system bus **6418**. It should be noted that other devices and/or systems of devices provide both input and output capabilities such as remote computer(s) **6444**.

Computer **6412** can operate in a networked environment using logical connections to one or more remote computers, such as remote computer(s) **6444**. The remote computer(s) **6444** can be a personal computer, a server, a router, a network PC, a workstation, a microprocessor based appliance, a peer device or other common network node and the like, and typically includes many or all of the elements described relative to computer **6412**. For purposes of brevity, only a memory storage device **6446** is illustrated with remote computer(s) **6444**. Remote computer(s) **6444** is logically connected to computer **6412** through a network interface **6448** and then physically connected via communication connection **6450**. Network interface **6448** encompasses communication networks such as local-area networks (LAN) and wide-area networks (WAN). LAN technologies include Fiber Distributed Data Interface (FDDI), Copper Distributed Data Interface (CDDI), Ethernet/IEEE 802.3, Token Ring/IEEE 802.5 and the like. WAN technologies include, but are not limited to, point-to-point links, circuit switching networks like Integrated Services Digital Networks (ISDN) and variations thereon, packet switching networks, and Digital Subscriber Lines (DSL).

Communication connection(s) **6450** refers to the hardware/software employed to connect the network interface **6448** to the system bus **6418**. While communication connection **6450** is shown for illustrative clarity inside computer **6412**, it can also be external to computer **6412**. The hardware/software necessary for connection to the network interface **6448** includes, for exemplary purposes only, internal and external technologies such as, modems including regular telephone grade modems, cable modems and DSL modems, ISDN adapters, and Ethernet cards.

FIG. **65** is a schematic block diagram of a sample-computing environment **6500** with which the disclosed subject matter can interact. The sample-computing environment **6500** includes one or more client(s) **6502**. The client(s) **6502** can be hardware and/or software (e.g., threads, processes, computing devices). The sample-computing environment **6500** also includes one or more server(s) **6504**. The server(s) **6504** can also be hardware and/or software (e.g., threads, processes, computing devices). The servers **6504** can house threads to perform transformations by employing one or more embodiments as described herein, for example. One possible communication between a client **6502** and servers **6504** can be in the form of a data packet adapted to be transmitted between two or more computer processes. The sample-computing environment **6500** includes a communication framework **6506** that can be employed to facilitate communications between the client(s) **6502** and the server(s) **6504**. The client (s) **6502** are operably connected to one or more client data store(s) **6508** that can be employed to store information local to the client(s) **6502**. Similarly, the server(s) **6504** are operably connected to one or more server data store(s) **6510** that can be employed to store information local to the servers **6504**.

What has been described above includes examples of the subject innovation. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the disclosed subject matter, but one of ordinary skill in the art may recognize that many further combinations and permutations of the subject innovation are possible. Accordingly, the disclosed subject matter is intended to embrace all such alterations, modifications, and variations that fall within the spirit and scope of the appended claims.

In particular and in regard to the various functions performed by the above described components, devices, circuits, systems and the like, the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (e.g., a functional equivalent), even though not structurally equivalent to the disclosed structure, which performs the function in the herein illustrated exemplary aspects of the disclosed subject matter. In this regard, it will also be recognized that the disclosed subject matter includes a system as well as a computer-readable medium having computer-executable instructions for performing the acts and/or events of the various methods of the disclosed subject matter.

In addition, while a particular feature of the disclosed subject matter may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms "includes," and "including" and variants thereof are used in either the detailed description or the claims, these terms are intended to be inclusive in a manner similar to the term "comprising."

In this application, the word "exemplary" is used to mean serving as an example, instance, or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the word exemplary is intended to present concepts in a concrete fashion.

Various aspects or features described herein may be implemented as a method, apparatus, or article of manufacture using standard programming and/or engineering techniques. The term "article of manufacture" as used herein is intended to encompass a computer program accessible from any computer-readable device, carrier, or media. For example, computer readable media can include but are not limited to magnetic storage devices (e.g., hard disk, floppy disk, magnetic strips . . .), optical disks [e.g., compact disk (CD), digital versatile disk (DVD) . . .], smart cards, and flash memory devices (e.g., card, stick, key drive . . .).

What is claimed is:

1. A system for configuring an industrial safety relay, comprising:

a memory that stores computer-executable components; and a processor, operatively coupled to the memory, that executes the computer-executable components, the computer-executable components comprising:

a graphical interface component configured to render a safety logic editor display comprising four columns of blank function targets for placement of graphical function block elements, to receive configuration input that associates graphical function block elements with respective blank function targets of the four columns of blank function targets, and to programmatically associate an output of a first function block element of the graphical function block elements with an input of a second function block element of the graphical function block elements in response to a reference parameter located on the second function block element being set to an identifier of the first function block element; and

a configuration component configured to create a configuration program for a safety relay based on the configuration input,

wherein the graphical interface component is further configured to enforce association of designated types of graphical function block elements to respective columns of the four columns, the four columns comprising:

a first column designated for placement of safety monitoring function block elements corresponding to respective safety input devices;

a second column designated for placement of AND, OR, or pass through logical operator function block elements;

a third column designated for placement of AND, OR, or pass through logical operator function block elements; and

a fourth column designated for placement of safety output function block elements corresponding to respective safety outputs of the safety relay.

2. The system of claim **1**, wherein a spacing between two of the four columns is fixed for all rows of the graphical function block elements.

3. The system of claim **1**, wherein a width of the graphical function block elements within one of the four columns is fixed for all rows of the graphical function block elements.

4. The system of claim **1**, wherein the configuration input further comprises input that creates a signal flow line between an output of a first function block element of the graphical function block elements in a first of the four columns to an input of a second function block element of the graphical function block elements in a second of the four columns in response to the configuration input.

5. The system of claim **1**, wherein a number of the blank function targets corresponds to an amount of memory available for creation of the configuration program.

6. The system of claim **5**, wherein the graphical interface component is configured to associate a graphical function block element, of the graphical function block elements, with a blank function target, of the blank function targets, in response to an input operation that drags the graphical function block element from a function tree to the blank function target.

7. The system of claim **1**, wherein the graphical function block elements are configured to display selectable elements using a first color that is different than a second color used to display non-selectable elements of the graphical function block elements.

8. The system of claim **1**, wherein inputs and outputs of the graphical function block elements are represented by respective circles located on the graphical function block elements and inside a periphery of the graphical function block elements.

9. The system of claim **1**, wherein the graphical interface component is further configured to display a tooltip window containing information regarding a status of a graphical function block element, of the graphical function block elements, in response to a cursor being hovered over the graphical function block element during runtime monitoring of the configuration program.

10. The system of claim **1**, wherein the graphical interface component is further configured to change a color of a graphical function block element, of the graphical function block elements, based on a status of the graphical function block element.

11. The system of claim **10**, wherein the graphical function block element is a safety output function block element, and the graphical interface component is further configured to, during a monitoring mode, cause the safety output function block element to blink between two different colors in response to a safety circuit associated with the safety output function block element satisfying a condition.

12. The system of claim **11**, wherein the condition comprises a ready state whereby the safety circuit is ready to be reset and is awaiting a reset command.

13. A non-transitory computer-readable medium having stored thereon instructions that, in response to execution, cause a system comprising a processor to perform operations, the operations comprising:

rendering, by a graphical interface component implemented by the processor, a safety logic editor display comprising four columns of blank function targets for placement of graphical function block elements, the graphical interface component enforcing association of designated types of graphical function block elements to respective columns of the four columns, the four columns comprising

a first column designated for placement of safety monitoring function block elements corresponding to respective safety input devices,

a second column designated for placement of AND, OR, or pass through logical operator function block elements,

a third column designated for placement of AND, OR, or pass through logical operator function block elements, and

a fourth column designated for placement of safety output function block elements corresponding to respective safety outputs of the safety relay;

receiving, via the safety logic editor display, first configuration input that associates graphical function block elements with respective blank function targets of the four columns of blank function targets;

programmatically associating, by a configuration component implemented by the processor, an output of a first function block element of the graphical function block elements with an input of a second function block element of the graphical function block elements in response to receipt of second configuration input that sets a reference parameter located on the second function block to an identifier of the first function block; and

creating, by the configuration component, a configuration program for a safety relay based on the first configuration input and the second configuration input.

14. The non-transitory computer-readable medium of claim **13**, wherein the rendering comprises rendering the four columns to have a fixed spacing between two of the four columns for all rows of the blank function targets.

15. The non-transitory computer-readable medium of claim **13**, wherein the receiving comprises receiving further configuration input that creates a signal flow line between an output of a first function block element of the graphical function block elements in a first of the four columns to an input of a second function block element of the graphical function block elements in a second of the four columns.

16. The non-transitory computer-readable medium of claim **13**, wherein a graphical function block element, of the graphical function block elements, comprises a safety output function block element, and the operations further comprise, during a monitoring mode, causing the safety output function block element to blink between two different colors in response to a safety circuit associated with the safety output function block element being in a ready state whereby the safety circuit is ready to be reset and is awaiting a reset command.

17. A method for configuring an industrial safety system, comprising:

displaying, by a system comprising at least one processor, a safety logic editing window comprising an array of blank function targets for placement of graphical function block elements, wherein the safety logic editing window enforces association of designated types of graphical function block elements to respective columns of the four columns, the four columns comprising

a first column designated for placement of safety monitoring function blocks elements corresponding to respective safety input devices,

a second column designated for placement of AND, OR, or pass through logical operator function block elements,

a third column designated for placement of AND, OR, or pass through logical operator function block elements, and

a fourth column designated for placement of safety output function block elements corresponding to respective safety outputs of the safety relay;

receiving, by the system via the safety logic editing window, first configuration input that associates graphical function block elements with respective blank function targets of the four columns of blank function targets;

programmatically associating, by the system, an output of a first function block element of the graphical function block elements with an input of a second function block element of the graphical function block elements in response to receipt of second configuration input that sets a reference parameter located on the second function block element to an identifier of the first function block element; and

creating, by the system, a configuration program for a safety relay based on the first configuration input and the second configuration input.

18. The method of claim **17**, wherein the displaying comprises maintaining a fixed spacing between adjacent columns of the blank function targets.

19. The method of claim **17**, wherein the displaying comprises maintaining a fixed width for the graphical function block elements placed on the array of blank function targets.

20. The method of claim **17**, wherein a graphical function block element, of the graphical function block elements, comprises a safety output function block element, and the method further comprises:

during a monitoring mode, causing the safety output function block element to blink between two different colors in response to a safety circuit associated with the safety output function block element being in a ready state whereby the safety circuit is ready to be reset and is awaiting a reset command.

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